CASSELL'S TECHNICAL MANUALS.

THE ARMS AND AMMUNITION OF THE BRITISH SERVICE.

BY

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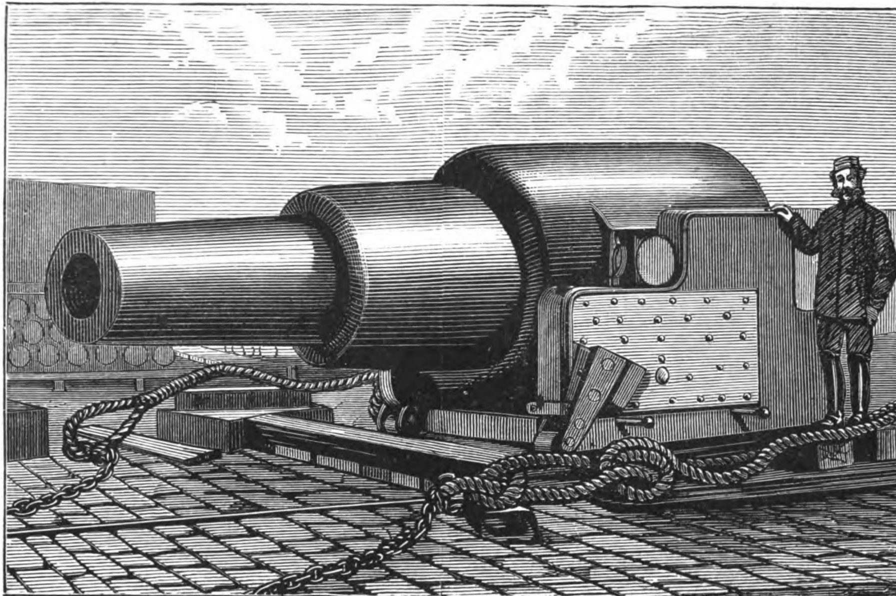

THE "WOOLWICH INFANT"—p. 53.

PREFACE.

THIS little manual originally appeared in the form of a series of papers, entitled "Weapons of War," in *Cassell's Technical Educator.* It was not known at the time of writing them that they would be reprinted in their present form, otherwise the subject might have been somewhat differently treated. But it has been urged that a reprint of these papers as they stood might prove useful to soldiers and volunteers. Some of the existing technical works on our *matériel* of war are too voluminous for the general military student; others are too sketchy and inaccurate. This little manual may at least lay some claim to the merit of having avoided both these faults; it can hardly be said to be too bulky; and it certainly is, as far as it goes, accurate. It may therefore, perhaps, satisfy a want which has hitherto remained unsatisfied between two extremes. Further, it should be stated that much of the information contained in this manual has been collected from Blue Books, Reports, and official documents which the general military student would often find it impracticable to consult.

It is hoped, therefore, that this book will be found to possess a substantial value, for the self-instruction of those

who have not the means, opportunities, or inclination for a more exhaustive study of the subject. It can hardly be doubted that there are many officers and non-commissioned officers and soldiers, especially in the Auxiliary and Reserve Forces, who are thus situated ; and to such this little manual is specially addressed.

The Author desires to acknowledge here the valuable assistance which he has received from three of his brother officers, Lieutenant-Colonel CLOSE, Captain STONEY, and Captain SLADEN,—to whom he is indebted for chapters xii. and xiii., on Artillery Carriages ; chapter x., on Rifled Guns ; and chapter xiv., on Ballistic Instruments. Pressed by other work, the Author thought he could not do better than invite the officers named above to undertake on his behalf the treatment of those branches of the subject of which they are respectively masters. The result has more than justified his expectations ; for it has furnished those chapters which the discriminating artillery student will probably rank highest in the book.

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INTRODUCTION.

IN order properly to appreciate the various improvements which through successive centuries have been introduced in weapons of war, and of which we see the combined results in the perfected arms with which the modern soldier is provided, it is essential first to recognise distinctly the object which weapons are required to fulfil. In this way alone can we hope to obtain a firm grasp of the relative merits of particular types and classes of arms, and of the considerations which have recommended this simplification and that modification, which have determined the rejection of one weapon and the introduction of another.

What, then, is the use and object of weapons of war? What principle has ever governed the advance of this branch of the world's industry and ingenuity? The answer to these questions is best furnished by a brief reference to the general history of the subject. The theoretical starting-point is that remote epoch when man attacked his enemy and his prey with the weapons with which Nature had provided him. We say "theoretical," because the actual existence of such an epoch is extremely doubtful, and in any case it must have been of insignificantly brief duration. That quality which distinguishes man from the brutes must early, if not immediately, have enlightened him as to the advantages to be derived from the employment of accessory means of attack or defence. By a strange contradiction, the

stream of almost Satanic ingenuity which since the time of Adam or of Cain has gone on widening, and deepening, and strengthening — the tide of invention which has brought us the cannon and the rifle, the shell and the torpedo, which has improved the rude guns of the fifteenth or sixteenth century into the Armstrong of the present, which has changed Brown Bess into the Martini-Henry, which has developed the "infernal machine" of Fieschi into the mitrailleur and Gatling battery of our own day—this stream took its rise in the God-like quality of reason. Man's intelligence at once prompted him to do that which was to the beasts, against whom his earliest wars were made, impossible, viz., to second his efforts by such assistance as he could draw from material resources. To weight the fist with a stone, to add force to the blow by means of a stick or club—such were the expedients at first adopted, and which we know, on the highest of all authorities, were employed in the daybreak of the world's history with fatal success. But, by degrees, that faculty which had suggested these rude auxiliary weapons, reached forward to other developments, and gave us the fashioned side-arm of definite form, the shaped weapon of stone or flint, of wood and bronze, of iron and steel. And then, as the study of the art expanded, it became obvious that a great advantage would result from the adoption of contrivances which would enable the enemy to be struck at a greater distance than hand-weapons permitted; and so we get to the class of missile weapons—to the javelin, the assegai, and others, to be thrown by hand; and the projectile weapons, such as the blow-pipe, for projecting poisoned darts, the bow, the cross-bow, and the sling; and the more powerful engines of war, such as the catapult and ballista. And now we strike the track which leads more directly down to our own age. The range of these projectile weapons

was so small, and their accuracy was so imperfect, while the importance of range and accuracy became so conclusively established, that the next considerable development naturally took these directions. At this point we mark the introduction of gunpowder, by which the ranges of offensive weapons and their practical importance were at once immensely increased.

With the introduction of fire-arms we mark, indeed, a new epoch, although the object remained the same—the killing or disabling of your enemy at the greatest distance, and with the greatest ease and certainty. The art received a new impulse; the "villainous saltpetre" breathed into it a new life; and since this time men have laboured with an unfailing zest at the perfecting of fire-arms, to the gradual pushing into the background of mere hand or missile weapons. During this period the successive improvements have nearly all taken the form of some advance in the production of long-range arms of precision or increased destructiveness. The greatest distance, the greatest and most irresistible certainty of destruction—these were the two main elements of success, the attempted achievement of which has advanced us from the blunderbuss to Brown Bess, from Brown Bess to the Brunswick rifle, from the Brunswick rifle to the Enfield, from the Enfield to the Henry, and Whitworth, and Metford. With cannon, in the same way, pressed by the same considerations, we have advanced from the rude appliances of the sixteenth and seventeenth centuries to the smooth bores which won the victories of Nelson and of Wellington, and, again, to the rifled guns of Armstrong, and Whitworth, and Woolwich. Again, from the simple round shot of an early age, or the rude and imperfect shell of the seventeenth century, we have travelled forward, always in the direction of increased destructiveness, to the shrapnel, and the segment, and the huge, far-

reaching common and double shell, with their enormous charges of powder, and to the Palliser projectiles, which set at defiance the stoutest armour-plating.

But, beyond a point, precision and range lose their practical value. Where exactly that line is to be drawn it is difficult to say. Some enthusiasts would probably place it at the limit of human vision ; practical soldiers, however, know that other considerations than these really determine the limits. At all events, when men had got to military rifles which would shoot with accuracy for half a mile or three-quarters, their instinct instructed them to seek to exercise their ingenuity in another direction. To multiply the rate of fire, within the limits already attained, became the problem of the day, and the result of the movement has been the introduction of breech-loading rifles of immense variety, and many of surprising excellence.

This brief and necessarily imperfect outline of the history of the subject will enable us to note the direction in which the tide of improvement has gradually but surely set, and to recognise, in a general way, the objects which the artillerist and the rifleman have endeavoured to attain.

But it is also important to recognise the influence of other considerations besides those of achieving determinate results. War is an art essentially of practice and not of theory ; and while theorists have been elaborating complex contrivances for the destruction of human life on the largest possible scale, the soldier has been ever at hand to exclaim, in his blunt way, "C'est magnifique, mais ce n'est pas la guerre." Simplicity in warlike appliances is a necessity of their existence, which unpractised designers are apt to overlook. Economy, too, is a consideration which the soldier cannot afford to disregard. Capability of resisting rough usage, transport, exposure, and climatic changes may also be classed among the essentials of

engines of war, the due observance of which limits the channel along which the military inventor must travel. In the case of warlike stores for English use, these considerations are especially important, on account of the scattered nature of our dependencies, the variety of climates to which the stores are likely to be exposed, and the certainty, that, in transport to our distant possessions, they will have much rough treatment to endure. This is a lesson which inventors, unfortunately, are slow to learn. They pursue a phantom of theoretical excellence, in utter disregard of the consideration that the soldier wants the real, not the ideal. They trample ruthlessly on the practical arguments which are opposed to their headlong progress, and push impatiently on one side the objections which those who know what war is venture to suggest. Even so distinguished a man as Sir William Armstrong has not steered clear of this rock. It is noticeable that, where his inventions in war *matériel* have trenched upon the province of the artilleryman proper—in his breech-closing arrangement, for example, in his fuzes, and his shells—they have all been more or less failures. When only mechanical, as distinguished from practical military considerations, were concerned, as in the structure of his guns, they have been eminently and entirely successful. To those readers who may now, or at some future time, conceive the idea of designing some weapon of war, we would give this serious advice: Whatever you may propose, be practical. Seek the advice, if you can, of some plain-spoken soldier; one who has seen service; one who knows something of the hurry, and confusion, and destruction of action, of the roughness of military transport; who can tell you of the rains and heats of India; who knows how clumsy are a soldier's fingers, and how little suited to ingenious refinements; one who can tell you, too, something of the

brilliant failures of scores of clever but unpractical inventions, of fair hopes and extravagant promises wrecked on the first contact with the rough touchstone of practice—one, above all, who will not mince matters, but will say plainly if need be, "Yours is the silliest and most unpractical invention which I have ever seen." He is the best friend to the inventor who speaks thus; he is the best friend also to his country, for he thus directs the inventive genius of the country into a useful course, instead of allowing it to filter itself away through vain channels into dreamland. On the other hand, we desire fully to recognise that the inventive mechanical genius and resource of England are among her native advantages, as substantial and important as her coal mines — advantages to be fostered and cherished by all means, and to be promoted by a liberal policy of encouragement on the part of the services and the Government.

If the present manual should have the effect of directing attention to war material, and stimulating the ingenuity of some who may honour it with their perusal, it will have accomplished more than the writer can dare to expect. He, on his side, would fail of his duty if he did not, with all emphasis, urge those who would enter upon the difficult and precarious path of improving our war material, to be, above all things, simple and practical. As Frederick the Great said, "What is not simple is not possible in war."

THE ARMS AND AMMUNITION

OF THE

BRITISH SERVICE.

CHAPTER I.

PORTABLE ARMS.

Weapons of war may be conveniently grouped into three main classes* :—

1. Portable Arms.
2. Artillery.
3. Special Instruments of Warfare.

Each of these classes admits of further and almost indefinite subdivision. We will proceed to consider them separately under their particular heads.

I. PORTABLE ARMS.—SIDE-ARMS.

Under this head are included all weapons borne upon a man's person. They are of two principal divisions :—

(1.) *Side-arms*. (2.) *Fire-arms*.

Under the head of side-arms are included swords, spears, lances, daggers, bayonets, pikes, javelins, arrows, and the like. The class is really a more comprehensive one than many persons suppose. The great advances made with fire-arms must be acknowledged to tend to push such weapons as swords and bayonets into a more subordinate position. If you can kill your enemy a mile off, the prospects of his being able to close with you are evidently less than when the range of your weapons was only a few score yards. Similarly, the great increase in

* The classes have been placed in the above order because that order is, to some extent, historical, and indicates roughly where the most ancient and most modern contrivances will generally be found.

the rapidity of fire of modern fire-arms renders less possible a successful charge of cavalry upon an infantry line or square, and by so much reduces the value of the sabre or the lance. But these considerations, which are perfectly just in themselves, have been pushed too far by theorists, and many have hastily and improperly jumped to the conclusion that the days of the bayonet and sword are gone by. To this the experience of the late Franco-Prussian war furnishes an emphatic contradiction. It is quite clear that despite the improvements in fire-arms, hand-weapons still possess considerable importance—that they may even determine the crisis of a stubborn fight. If an obstinate enemy cannot be dislodged from his entrenchments by a musketry or artillery fire, against which his defences may afford him ample protection, he must be driven out with the bayonet, at whatever cost, and this was accomplished more than once in the war of 1870; while, although cavalry may no longer be employed to ride down infantry squares, they will still be required to sweep over the fields of battle, to complete a disorganisation already commenced, to convert a retreat into a rout, to drive home the wedge which the rifle and cannon have inserted. Here, therefore, we see a continued use for the bayonet, the sword and the lance; and, accordingly, we find all these weapons retaining their place in the British service.

There are a considerable variety of swords in use in our army—the whole being made at the Royal Small Arms Factory at Enfield. The principal types of swords are those for the cavalry, and the navy cutlass. Of the other ten sorts of swords enumerated in the official vocabulary, the greater part are for sergeants, for Highland regiments, for volunteer non-commissioned officers, etc. Pioneers have a sword with a saw-back, which is found useful in sawing through wood, removing obstacles, and doing some of the special work which pioneers are required to perform. It is noticeable that there is a growing tendency to utilise hand-weapons for more than one purpose. This is perhaps a natural result of the decreased importance of these weapons for the particular purpose to fulfil which they were originally introduced.

We thus find that the latest pattern of bayonet—that which has been proposed for use with the Martini-Henry rifle—is at once a sword, a saw, and a bayonet. This weapon has been favourably reported upon. It serves to saw fire-wood on an emergency; it may be useful for clearing away light obstacles; and it gives the infantry soldier what the simple bayonet does not, an efficient hand-weapon for personal defence or attack. This is a more useful combination than that which has been proposed by some inventors—viz., to combine in one a spade or trowel and a bayonet, or to make the bayonet so broad and flat that it could be worn round the neck as a piece of defensive armour for the breast. We have seen specimens of both these weapons, and have recognised in them the handiwork of the unpractical inventor. If the bayonet is to be utilised for more than one purpose, the best combination is undoubtedly that described above—of a sword, a saw, and a bayonet, the handle serving to attach it to the barrel of the rifle.

Some of the best—probably the best—swords in Europe are manufactured at Solingen, in Rhenish Prussia. Not less remarkable than the excellence of these weapons and their fine temper, is their cheapness. An infantry officer's regulation sword, with scabbard complete, can be bought at Solingen for something under £1; an artillery officer's sword for about a guinea. If purchased of good London makers, these weapons cost from £4 to £5; but the London swords, the blades for which are generally obtained from Birmingham, are in no respect better than those made at Solingen.

Visitors to the Paris Exhibition of 1867 will not readily forget the magnificent exhibition of sword cutlery furnished by M. Carl Reinh Kirschbaum, of Solingen, and which, although surpassed in decorative excellence by some of the French makers, whose highly ornamental and costly swords are rather examples of goldsmiths' than of cutlers' work, was unequalled for solid excellence and cheapness by any swords in the Exhibition. The Solingen makers prefer cast steel to damascened blades; the introduction of the iron by which the damascened appearance is produced being considered apt to soften the sword and spoil its high character, which is estimated in a great degree by

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the just and complete "return" of a blade after bending. All sword-makers are very far from agreed upon this point. By some it is thought that the extent to which a sword will bend is even more important than its perfectly accurate return to straightness after bending.

On this point the author made the following remarks in his official report on the "Portable Arms" in the Paris Exhibition:—"The power which a blade may have of straightening again is accepted by the Solingen makers almost as a crucial test of its excellence; and when a sword is bent to a point beyond which it can return perfectly straight, they would almost prefer it to break than that it should exhibit softness and remain crooked. On the other hand, it is argued by some that, although it is well that a sword should straighten, it is better that it should remain permanently bent than that it should break, a bent sword being more serviceable than a broken one; and the Solingen makers are considered to lay undue stress upon the straightening qualities of the sword. As, however, the flexibility of a blade depends, after its quality, upon its transverse section, and as Solingen exhibits swords which will bend almost round a man's body, it would seem as though all the flexibility that could possibly be desired can be obtained without any admixture of iron. When a Solingen maker says he prefers that his sword—if it be bent beyond what it is capable of standing—should break rather than remain crooked, the burden of proof rests upon others of showing what useful purpose would be served by making a blade capable of bending further at the expense of some softness."

Next to the sword and the bayonet—weapons which we have seen are coming, in the hand of the infantry soldier, to be combined—the lance is the most important of military hand-weapons. Skilfully used, the lance is a most formidable weapon; unskilfully used, it becomes a terrible encumbrance. In India the lance is largely employed. It is peculiarly useful in pursuits or in isolated combats. A few years ago the bamboo staff was adopted for the lance of the British soldier, as being lighter than ash. Of the head of the lance there is not much to be said, except that it should be made of a good quality of steel, and of a form favourable to inflicting a serious wound. In the

British service, the triangular head is preferred to the simple conical point.

It is unnecessary, we think, to dwell at any greater length upon the subject of weapons of the sword and lance class; nor is it worth while to touch upon the assegais of Africa, the arrows of the Indian, or the javelins and spears still in vogue among some of the ruder nations. The consideration of these weapons can have no practical value. They are interesting rather from an antiquarian point of view, and as so many examples of the ingenuity of man in producing a large variety of means of attack and defence. The projectile weapons—such as the javelin, the djerid, and the arrow—have completely lost their importance now that fire-arms have reached so high a pitch of development, and can be procured even by the poorest and most savage nations. Even hand-arms proper, such as swords, lances, and bayonets, have faded into a subordinate and wholly secondary position, although, for special purposes, they must ever retain a certain value. But we must hasten on to the more interesting branch of our subject, and to the consideration of fire-arms, about which we shall have much to say.

CHAPTER II.

MUZZLE-LOADING SMALL ARMS.

THE division of our subject which we have now to consider is the important one of fire-arms. We have seen how the introduction of fire arms has had the effect of pushing side-arms into the background, how each successive development of fire-arms has by so much reduced the practical value of swords, and spears, and lances, and the like. We have noted also that the tide of improvement has always set in the direction of increased range, increased accuracy, increased destructiveness, increased rapidity of fire.* These are the elements of the problem which the gunmaker has for several centuries been striving to solve, checked, however, and circumscribed in his action by the practical considerations which

* See Introduction.

military necessities impose. Thus the exquisitely accurate match-shooting rifles which we see at Wimbledon, with all their refinements for ensuring good shooting—the carefully weighed charges, each in separate bottles, the delicate sights, the light triggers, have never come in for military use, because they fail in the first element of a military arm—simplicity. Again, the far-reaching Metford rifle, with which good practice has been made at 2,000 yards, is not a possible military weapon because of its refinements, and because also of its weight, and of the heavy charge which it requires. Many of the ingenious breech-loaders, in the production of which unhappy inventors have spent their time, their brains, and their money, fail altogether—despite their points of excellence and their rapidity—to satisfy the simpler wants of the soldier. But although let and hindered by these considerations—although continually being turned back from the dazzling path of ideal excellence, and warned out of the dangerous byeways of theoretical refinements—although continually being reminded of the necessity of keeping to the somewhat tame and dusty high-road on which the soldiers are soberly tramping—a road which to some probably appears as straight and dull as those famous military roads of the Romans—despite these restrictions, the gunmaker has succeeded in making very considerable advance in the direction required.

For many years the arm of the British soldier was a smooth-bore musket, familiarly known as "Brown Bess." This arm had a barrel of about three-quarter inch diameter (·753 in.), and threw a spherical leaden ball, which weighed 483 grains, with a charge of four and a-half drams of powder. It will easily be understood that such an arm was neither accurate nor far-reaching. The charge of powder was large enough, it is true, to project the bullet with a high velocity, but the size of the bullet caused it to meet with great resistance from the air, and thus soon to lose its velocity, besides being liable to be easily deflected. Moreover, being fired from a smooth-bore barrel, it was subject to all the disturbing causes common to smooth-bore projectiles. Among these causes may be prominently named :—(1) windage, which is the difference between the diameter of the bullet and that of

the bore, and which, by allowing the passage of the gas over the bullet, causes it to proceed through the bore with a sort of bounding motion, and to leave it in an accidental direction, according to the position of the last impact against the bore; (2) irregularity of form and surface of the projectile; and (3) eccentricity of projectile. The result of these accumulated defects was that Brown Bess, although it would range effectively up to about 200 yards, could hardly be depended upon for even approximate accuracy up to half that distance. There used to be a saying among soldiers that if you fired at the church you might think yourself lucky if you hit the parish! The smooth-bore musket is not to this day entirely obsolete in our army. For example, the native infantry regiments in India are armed with a smooth-bore musket, which is in some respects superior to "Brown Bess," and has a smaller bore (·656 inch). The native Indian police have also smooth-bore carbines; and some of our coast-guard are still armed with smooth-bore pistols. Indeed, in some distant colonies we believe that even "Brown Bess" herself may still be found.

After Messrs. Minié and Delvigne had shown how, by the adoption of a conical expanding bullet, an effective military rifle might be made, several of the old smooth-bore muskets were rifled with three grooves, and re-issued as rifled muskets—chiefly for naval use. By this means the weight of the bullet was increased to 825 grains, and the range, accuracy, and effective power of the arm were immensely improved. Compared with Brown Bess plain, Brown Bess rifled was an excellent weapon; although in these days of small bores we should smile at a bullet three-quarters of an inch in diameter.

The first rifled arm possessed by the British soldier was the Brunswick rifle. This arm had two grooves, and fired a belted ball, which was covered with a patch, the grease upon which, according to Mr. Kaye, determined the outbreak of the Indian mutiny. The bullet weighed 555 grains. The loading was tedious and inconvenient, owing to the belt on the ball having to be carefully adjusted in the groove, and to the great amount of friction; and the weapon, although vastly superior in range and accuracy to the smooth-bore, was comparatively inefficient

as a rifled arm. Our rifle regiments and sharpshooters were armed with it. The Sikh regiments in India are, if we mistake not, still armed with the Brunswick rifle.

But the really important improvement in military fire-arms was due to the labours of Messrs. Minié and Delvigne. We by no means wish to underrate the exertions of other workers in the same field; and prominent among those who laboured to bring into notice the principle upon which the success of Messrs. Minié and Delvigne depended was Captain Norton, who unquestionably invented and exhibited at Woolwich, as far back as 1823, an elongated expanding shot and shell, identical in principle with the Minié bullet. But it was not until 1851 that the Minié rifle was introduced. The arm was rifled in four grooves, and was intended to fire a conical leaden ball with a hollow in the base, into which was fitted an iron cup. The object of this arrangement was to enable the bullet to be readily loaded, the diameter being less than that of the bore, while by the action of discharge the iron cup would be driven forward into the conical hollow, expanding the bullet. A French colonel named Thouvenin had tried to accomplish the same object in a different way. He placed a small iron pillar or *tige* at the bottom of the bore, and on to this the bullet was rammed until it was expanded. The *carabine à tige* was used by the Chasseurs d'Afrique in 1846 in Algeria, but it was obviously open to some strong objections, such as the liability of the *tige* to become bent or broken, the delay in loading, the want of uniformity in expansion, and the disfigurement of the bullet. The Delvigne-Minié system was a great improvement on this. The loading was effected almost as easily and rapidly as in a smooth-bore; and the expansion of the bullet depended not upon the exact amount of force or hammering given to it by the soldier, but upon the pressure exerted upon the iron cup by the powder gases at the moment of discharge. The arm, as at first introduced, was, however, open to some practical objections. In the first place, the iron cup was found liable in some instances to be blown through the bullet, which was left a distorted cylinder of lead inside the barrel, the weapon being thus rendered for the time unserviceable. In the next place, the calibre was too large

for accurate long-range shooting—viz., ·702 inch. The weight of the bullet was also objectionably great from a military point of view, being 670 grains. With so heavy a bullet the soldier, if provided with a sufficient supply of ammunition, was inconveniently over-burdened. So in 1853 a modified Minié rifle was introduced, with a bore of only ·577 inch, and three grooves, which fired a bullet of 530 grains with 70 grains of powder. The iron cup was replaced with a box-wood plug. The reduction in the weight of the arm with sixty rounds of ammunition was three pounds. This was the famous Enfield rifle—the weapon which won Alma and Inkermann, and which at this moment, whether in its muzzle-loading or converted breech-loading condition, is the arm of the greater part of our regular army and reserve forces. But since the introduction of the Enfield rifle in 1853 several improvements have been made in the ammunition, which have greatly increased the efficiency of the weapon. The two most important of these improvements were, the substitution of beeswax for a mixture of beeswax and tallow, for the lubricating material; and the reduction in the diameter of the bullet. Both these changes were suggested by Colonel (now Major-General) Boxer, and contributed in an important degree to the efficiency of the ammunition and the arm. The adoption of beeswax was recommended on the ground that in hot climates the tallow melted, leaving the rifle unlubricated, besides which the acid in the tallow caused the corrosion of the bullets. The wisdom of adopting pure beeswax was stoutly disputed at the time, and has been frequently disputed since. But repeated experiments and inquiries have fully established the efficiency of beeswax, and in the advertisement which was issued to the competing gunmakers in 1866, it was laid down that "wax on the bullets is indispensable;" and the evidence which the late committee on small arms took upon this subject led them to lay down positively that the "lubrication should be pure beeswax, as best adapted to withstand variations of climate and long keeping." This is a practical point upon which it seems important to insist. Inventors of ammunition are very fond of submitting fancy lubrications of their own, and it is well, therefore, that it should be distinctly

understood that the question of lubrication for military small-arm ammunition has been most fully and patiently considered, and decided definitively in favour of pure beeswax. In the Royal Laboratory at Woolwich the greatest care is taken to ensure the perfect purity of the beeswax, which is all subjected to a careful chemical examination.

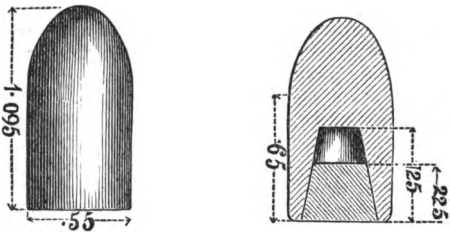

Fig. 1.—BULLET USED IN ENFIELD RIFLE.

The second important change which was made in the ammunition was in the reduction of the diameter of the bullet. It was found in India, during the mutiny, that great difficulties occurred in loading owing to the size of the bullet, which was at first fixed at ·568 inch, leaving a windage of only ·009 inch—quite insufficient, when the rifle became foul, to admit of easy loading. Many instances occurred in which loading was almost impossible. The men were seen striking the ends of their ramrods against walls and trees, to drive home the bullet, and the evil was so serious as to have threatened at one time to lead to the abandonment of the Enfield rifle. But some experiments, which were carried out by Colonel Boxer, showed that it was possible to reduce the diameter of the bullet considerably without affecting the accuracy of shooting. He found that a reduction of diameter from 0·568 inch to ·55 inch (giving a windage of ·022 inch) might be safely made, and the loading difficulty was thus completely overcome. Other minor changes have been made, as, for example, the addition of a cut through the paper surrounding the bullet, in order to cause the

paper to disengage itself from the bullet in flight; the adoption of an improved powder, more uniform in its action, and better adapted to secure the just expansion of the bullet; the substitution of a baked clay plug for one of box-wood, which, as before stated, had superseded the iron cup of the original Minié. The iron cup was given up because it was liable to be blown through the bullet; the box-wood plug was given up on account of the cost of box-wood; and the clay plug was adopted as being inexpensive and efficient. The part which the plug plays in the action of the bullet must be noticed. It is generally spoken of as the expanding agent. This is true to a certain extent; but the expansion can also be secured without any plug. In the Pritchett bullet, for example, which for some short time was used with the Enfield rifle, there is only a shallow hollow, and the expansion is due partly to the action of the gas within this hollow, and partly to the "upsetting" of the bullet, which is due to its inertia. Other bullets—the Whitworth, for example—depend entirely upon the "upsetting" or "overtaking" action. But the plug serves a further and important purpose. It is a supporting as well as an expanding agent. The Pritchett bullet was found to foul, from the simple reasons that the expansion was not so promptly effected as in a plugged bullet, and thus a rush of gas over the bullet became possible, and that when the barrel had become foul, the expanded sides of the bullet, having no internal support, collapsed on coming into contact with the fouling deposit. The plug, therefore, serves a threefold purpose:—1. It ensures the expansion. 2. It makes that expansion so prompt and rapid that the chance of an escape of gas over the bullet is diminished. 3. It supports the expanded sides when the rifle has become foul.

The construction of the Enfield rifle cartridge is shown in Fig. 2 on the next page. It consists of a hollow rolled cylinder of paper, or rather a double cylinder, since the part which contains the powder is a separate cylinder contained in the outer envelope, by which the bullet is attached. The lubrication is applied on the outside of the paper which surrounds the bullet—up to the shoulder of the bullet—which, as every rifle volunteer knows, is loaded with the paper upon it, the

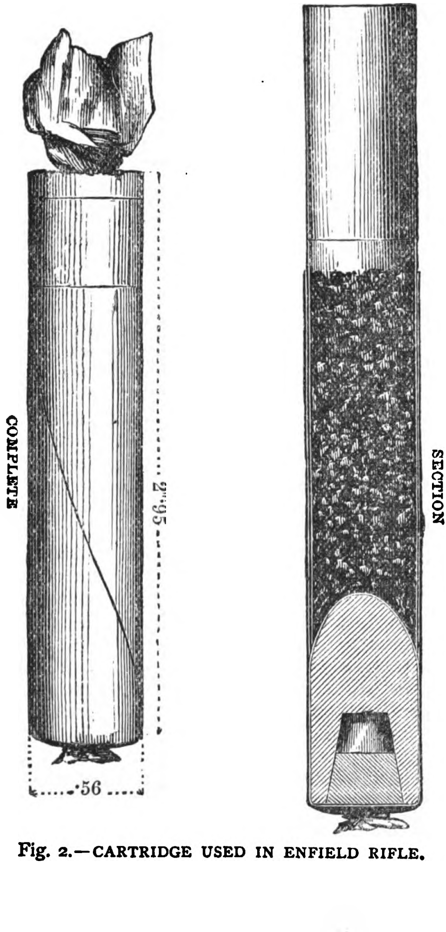

Fig. 2.—CARTRIDGE USED IN ENFIELD RIFLE.

top of the cartridge being first torn off, the powder poured into the barrel, the papered bullet inserted in the muzzle, the rest of the cartridge being torn off and thrown away, and the bullet rammed home. The ease of loading with the ·55-inch bullet is so great, that in a clean arm it is possible to load without the ramrod, by striking the butt against the ground.

The bullets are made of perfectly pure lead, the purity of which is tested by chemical analysis. Any impurity tends to alter the weight and to affect the expansion, and thus to spoil the shooting of the arm. The bullets are all made by compression—the lead being first squirted into long rods—and then formed into bullets in a machine, which is one of the sights of Woolwich Arsenal. The weight of each bullet, with the plug, is 530 grains; and the accuracy of manufacture is so great that the working limits are only two grains over and under the mean weight. The charge of powder is seventy grains. The Enfield rifle is capable of shooting with great accuracy up to about 800 yards, and good practice has been made with it occasionally at longer distances. But 800 yards may practically be regarded as the extreme limit of accuracy of a bore so large as ·577 inch, unless the weights of bullet and powder were unlimited, which, in view of the soldier's requirements, of the quantity of ammunition which he has to carry, and of the amount of "kick" or recoil which he can endure, they cannot be. We have omitted to mention that the pitch of rifling of the Enfield is one turn in six feet six inches; the grooves are ·235 inches wide, and ·005 inch deep at the muzzle, and ·013 inch deep at the breech. The weight of the arm is as nearly as possible nine pounds. The weight of sixty rounds, packed for service, with the proportion of ninety caps, is about five pounds eleven ounces. The same ammunition is used with all muzzle-loading rifled muskets of ·577 bore. A similar cartridge—differing only in the weight of the charge of powder, which is reduced to two drams—is used with all muzzle-loading carbines of ·577 bore. The carbines and the short rifles are for the most part rifled with five grooves, and a pitch of one turn in forty-eight inches. This disposition of rifling is more favourable to accuracy than the three grooves and slow

pitch. Some oval-bore Lancaster rifles are in use in the service. This rifle has no grooves. The bore is oval, and the oval being disposed spirally along the barrel gives the necessary spin to the bullet. The oval is at muzzle, major axis = ·593 inch, minor axis = ·577 inch; at breech, major axis = ·598 inch, minor axis = ·580 inch. The same ammunition is used with the Lancaster as with the Enfield rifle. The shooting of the Lancaster is, however, decidedly superior.

CHAPTER III.

BREECH-LOADING SMALL ARMS.

BEFORE quitting the subject of muzzle-loading small arms, it may be well to notice the means of ignition usually employed with arms of this class. Nearly the earliest and rudest mode of igniting the charge consisted of a fuze or slow match, which was applied to a small charge of powder placed over the "touch-hole," or vent, as it is now called. A grave inconvenience of this system consisted in the fact that arms could hardly be carried ready primed, at least for any length of time, because the priming was liable to drop out, or if it did not drop out, to become damp. Accordingly the soldier was compelled to prime his gun just before using it; and as the operation had to be carefully performed, rapidity of fire under the system was out of the question; moreover, the carrying of an ignited match attached to the gun was a source of inconvenience and danger. The match was superseded by the flint-lock, the flint being made to strike a spark as it descended on to the priming charge of powder. In some instances a metallic alloy of iron and antimony was substituted for the flint. The action in both cases was the same; sparks being struck into the priming charge. Here we come more closely to our present lock and hammer. A spring-lock was necessary to bring the flint violently down, and the hammer by which the flint was held was the direct parent of the hammer by which the percussion cap was afterwards fired. The next important advance consisted in the application of the percussion

system to the firing of small arms. It is said that a Scotch gunsmith, called Forsyth, was the first who proposed a percussion fire-arm, for which he took out a patent in 1807; but it was not, we believe, until about 1822 that a percussion musket was introduced—at least in this country—for military use.

It is hardly necessary to insist upon the advantages which the percussion cap presents over the match and flint-lock guns. A moment's consideration will serve to show that the change was a most important one, scarcely less important in its way than the introduction at a later period of breech-loading. To detail the various simplifications and improvements of the lock which have been effected would be tedious; nor is it necessary to set forth the endless varieties of percussion caps and devices for igniting fire-arms by means of detonating composition which have been proposed and attempted since the subject of this improved method of firing was first suggested about sixty years ago. It will be sufficient to say, that the percussion caps for military arms, with the form and appearance of which all our readers are no doubt familiar, are made of pure copper of a superior quality. It is necessary to use good copper, not only because a very small admixture of foreign matter, by affecting its malleability, will interfere with the production of a cap of the required form, but because too hard or brittle a metal would be apt to fly and injure the firer. Partly on this account, and partly because of the liability of zinc to corrosion, the proposition which has been frequently made to substitute that metal for copper has always been held to be inadmissible. For a similar reason our readers should be cautioned against employing, if they can avoid it, the cheap brass caps which are not unfrequently manufactured and coloured to represent copper. In the Government establishments very careful attention is paid to the selection of the copper.

Cap composition varies with different makers, and from time to time it has been altered for military arms. Thus, the composition for the caps for the Enfield consisted of—

	Parts.
Fulminate of Mercury	4
Chlorate of Potash	6
Ground glass	2

—the latter ingredient being added to increase the sensitiveness of the composition, by promoting friction between the particles. When the Westley-Richards and the Sharp breech-loaders were introduced, with which the cap was required to ignite the powder contained in a paper cartridge, a more powerful composition was introduced, namely :—

	Parts.
Fulminate of Mercury	4
Chlorate of Potash	1

This composition proved, however, too violent in its action for use on the nipples of the Enfield rifle, which are of a different form from the nipples of the breech-loading rifles, with which the caps were intended to be used, and a further change was made to a composition consisting of

	Parts.
Fulminate of Mercury	6
Chlorate of Potash	6
Sulphide of Antimony	4

The addition of the antimony secured the flash which was required to pierce the paper envelope of the cartridge, while at the same time it modified the intense violence of the cap, and prevented it from "flying" into pieces, and causing inconvenience and injury to the firer.

One more point with regard to percussion caps, and we pass on to another subject. This point is the waterproofing of the cap. Several methods have been tried, and are in vogue for rendering percussion caps waterproof; or, which is of more importance, for enabling them to resist damp. Among these may be mentioned the covering of the composition with a thin metallic disc, or with a disc of india-rubber. The simplest and probably the most effective plan is that which is applied to the Government caps, viz., to subject the composition to considerable pressure, by which means it is reduced to a stony hardness, and is rendered almost impervious to moisture; while by coating the composition with a strong varnish of shellac the caps are ultimately made completely waterproof.

We have now dealt generally with all the points which connect themselves with muzzle-loading rifled small arms.

We have considered the bullet, the charge, the means of ignition, the rifling, the weight and character of the arms. These elements, judiciously combined, gave us in the Enfield rifle a military weapon of great excellence. But there were two important directions in which improvements seemed necessary and possible. The first and most important consisted in increasing the rapidity of fire; the second in increasing the ballistic power of our weapons, an expression which covers all the shooting qualities of an arm—its accuracy, range, flatness of trajectory, penetrative powers, etc.—as distinguished from those qualities which connect themselves with easy and rapid loading, etc.

In short, the advantages of the Enfield rifle as an arm of precision were no sooner recognised than men began instinctively to endeavour to simplify and accelerate the operation of loading by introducing the cartridge at the breech. In the case of the cavalry soldier this was a matter of no small importance. The difficulties of loading a rifled arm on horseback were considerable; and thus we find that as early as 1857 steps had been taken towards the supply of breech-loaders to mounted men. In that year some Sharp breech-loading carbines were issued to two regiments of cavalry. The charge in this arm was inserted bodily at the breech; and as the block ascended it cut off the end of the cartridge, and exposed the powder, which was fired in the same way as a muzzle-loader, with the ordinary percussion cap. The Sharp breech-loader, which is still used to some extent by our cavalry in India, is an extremely bad breech-loader, for several reasons—among them the great escape of gas which occurs at the breech on firing, and the employment of a percussion cap.

The Westley-Richards carbine was a great improvement on the Sharp, for the end of the cartridge was not cut off in loading, and the escape of gas was prevented by means of a felt wad attached to the back of the cartridge. In this wad we see a sort of rude prototype of the present non-consuming cartridge—an imperfect application of the present system of making the cartridge do the work of checking the escape of gas. We recognise here, also, in this half solution of the question, a dim perception of the fact now so fully admitted, that the cartridge is

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turning-point or hinge upon which the success of a breech-loading small arm depends. Here, for example, we have, in the Westley-Richards, a superior combination to that which existed in the Sharp; and why? Not because of the superiority of the breech-action of the Westley-Richards, for it may be doubted if the Sharp action (upon which the present admirable Henry breech-loader is based) is not in fact the better of the two. No; but simply because Westley-Richards was on the right track with regard to his cartridge, and Sharp was on the wrong track. It should here be mentioned that, as an arm of precision, the Westley-Richards carbine was a very good one. It was a "small-bore" rifle—an expression to which we will assign a definite meaning hereafter—and it threw a 400-grain bullet, with a 2-dram charge, with great accuracy to a long range. But the rifle (which is now, we believe, in the hands of the yeomanry cavalry) is open to several objections—among them, that it is fired in the old way by means of a percussion cap. So long as this mode of ignition is retained, it is impossible to realise the full advantages of a breech-loader. It is fair, however, to observe that it was through no fault of the inventors that this objectionable feature in the Sharp, Westley-Richards, and other breech-loading rifles was retained. The fact is that the authorities set their faces determinedly against cartridges containing—like those now in use for the Snider—their own means of ignition. It was supposed that such cartridges were liable to accidental explosion *en masse* by the ignition of a single cartridge in the barrel or box, and the consequences of such an accident were likely to be so serious that any cartridge of this description was considered inadmissible. We thus perceive that a serious barrier existed at this time to the development of the breech-loading question. It was regarded as essential to employ the old muzzle-loading means of ignition, and greatly accelerated rapidity of fire—one of the principal, though not the only, advantage of breech-loading—was impossible with a capping breech-loader; so that for several years the question was considered mainly as a cavalry question, facility, but not rapidity, of loading being the thing aimed at. Indeed, rapidity of loading

was rather deprecated than otherwise. Many good soldiers and experienced officers declared that if you gave a soldier a gun which he could load very quickly he would expend all his ammunition before he came within effective fighting range. It may be admitted that breech-loaders are open to this objection, although not to anything like the extent commonly supposed, and the objection is one which can be remedied by discipline and an effective, careful training. The practice of the Prussians is an example of this. Here we have a nation which really understands the breech-loader, which is properly trained in its use and in the economical expenditure of ammunition, and the results we have seen in two great wars. On the other hand, we have the excitable, and, we may be permitted to add, badly-trained, ill-drilled, ill-disciplined French soldier, blazing away at any number of mètres from the enemy, and running out of cartridges early in the day. Cannot the English soldier do what the Prussian does? Is our national temperament so excitable, so unlike that of the Prussians, that no training can teach our men that the fighting unit is a man *plus* a cartridge, not a man by himself with an empty pouch? Then, again, it is to be observed that although a somewhat wasteful expenditure of ammunition may be one of the results of the introduction of breech-loaders, the non-issue of breech-loaders would be tantamount to the destruction of the army. If a soldier is likely to fire too rapidly in the one case, he is certain to be unable to fire rapidly enough in the other. The one defect may be corrected or controlled; the other, so long as muzzle-loaders are in use, cannot be. It is not a question of expediency, it is a question of sheer necessity. Whether or not breech-loading rifles may be attended with certain disadvantages is a point which admits of discussion, but it admits of no discussion that breech-loading rifles are vital to the very existence of an army. If the disadvantages are there they must be made the best of; and the way to make the best of this special disadvantage is so to train the soldier, so to drill and discipline him, so to hammer at him, that he will come to understand that a shot ought never to be thrown away. And if he only act upon this principle, it will be no objection that

he is able to fire a dozen shots a minute instead of three, and thus do his work in one-fourth the time.

What we have written may appear to have an historical rather than a practical interest. A little consideration will, however, serve to show that this is not the case. It is in the history of the subject that its foundations repose. In the recognition of the difficulties which beset the earlier attempts, the objections which stunted the growth of the question—in the perception of the growing importance of the cartridge question, and the relatively inferior importance of the breech mechanism—in the recognition of the fact that the question of breech-loading is quite distinct from and independent of the question of shooting—of ballistic power—we have the elements of the subject. Let us pass now to their practical application.

Up to about 1864 the question of breech-loading was treated, for reasons which we have endeavoured to trace in outline, as one which principally affected the cavalry soldier. But in 1864, instructed by the experience of the Dano-German war, General Russell's committee recommended that the British infantry be armed with breech-loaders. The question then arose, What breech-loader should be provided? I need not trace all the discussion which took place at the time, or set forth the arguments which ultimately prevailed to secure the adoption of the Snider system of conversion. The Enfield rifle was thought—and properly thought—to be so excellent a shooting weapon, that it was considered that it would be sufficient, at least for the present, if this rifle were provided with an arrangement which, without affecting its shooting, would permit of its being fired more rapidly. In this way, while the British army could be rapidly re-armed with an effective breech-loader, ample time would be given for working out the question which would still remain of a totally new breech-loader for future manufacture. About fifty systems of conversion were submitted to Government, in reply to an advertisement dated August, 1864. Of the five systems which were preferred by the committee only one was a non-capping breech-loader, and that was the Snider. Ultimately, after some extensive trials, the Snider was adopted. Most of our

readers are probably more or less familiar with the breech-action of the Snider rifle—the block hinged upon the side of the "shoe," and containing the piston or striker, by means of which the blow is communicated from

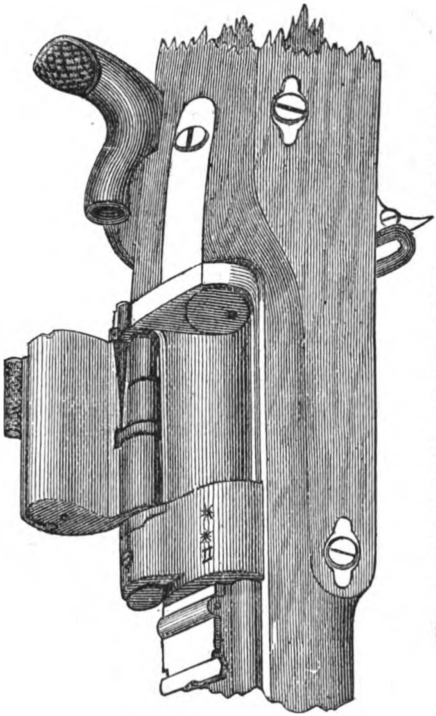


Fig. 3.—SNIDER RIFLE OPEN FOR RECEPTION OF CARTRIDGE.

the hammer to the cap. Those who are unacquainted with this arm will be able to understand its construction from the accompanying illustrations (Figs. 3 and 4).

The whole of the serviceable long and short Enfield rifles have been converted into breech-loaders on this system ;

and these, with the addition of some thousands of ***new*** Snider-Enfields, give us about 700,000 Sniders on hand. The regular army, and we believe the militia, are already armed with this weapon; the armament of the volunteers

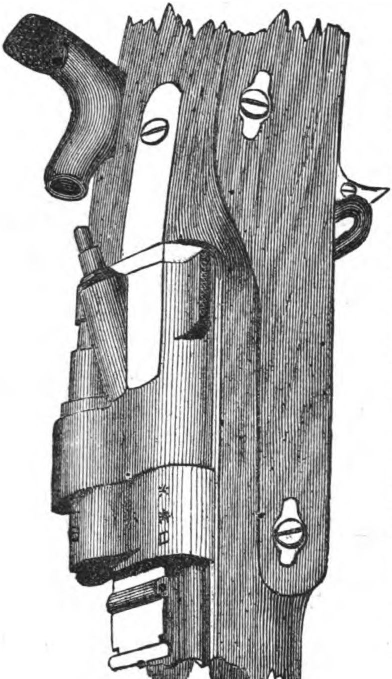


Fig. 4.—SNIDER RIFLE CLOSED AFTER RECEPTION OF CARTRIDGE.

is now proceeding, if not actually complete. The Snider rifle was subjected to a good deal of hostile criticism on its first introduction, which has been sufficiently answered by the experience of the past three or four years. We now hear little censure of the arm. It is obviously open to the

objection that the calibre is too large, and that it is comparatively inferior as an arm of precision, and even as a breech-loader, to some of the more modern examples of military breech-loading arms; but the simplicity, efficiency, and durability of the breech mechanism are now universally admitted; and as for its shooting qualities, the weapon is at least as efficient as the Enfield rifle. With regard to the durability of these arms, it may be mentioned that the writer has seen several Snider rifles which have fired 40,000 and 50,000 rounds: he has seen one which has fired over 70,000 rounds, and which is still serviceable.

We have yet to speak of a very important element in the new arm—the cartridge. It is not too much to say that it is rather to the cartridge than to the breech mechanism that the arm owes its success. The breech mechanism, it should also be understood, was not an easy one to construct a cartridge for, because (1) in the event of a failure on the part of the cartridge, the block was liable to be blown open; (2) the difficulty—we might say, the impossibility—of making the block fit accurately and closely against the base of the cartridge rendered the strain upon the cartridge case peculiarly severe; (3) the extraction of the empty case had to be performed by hand, and without any leverage or mechanical assistance, and therefore must be easier than is necessary for guns in which "power" can be applied. But there were other conditions besides those of strength and easy extraction which the cartridge is required to fulfil. What they were, and how they have been satisfied, will be explained in the next chapter.

CHAPTER IV.

BREECH-LOADING SMALL ARMS (*continued*).

WE have spoken of the introduction of the Snider-Enfield rifle, the present arm of the British soldier. It is necessary, however, to say something more on the subject of the cartridge for this arm, because it is now recognised that the cartridge really constitutes the soul of any system

of breech-loading small arms. The cartridge has been compared to the hinge upon which the system turns; once select a good cartridge, and the difficulty of finding a good rifle is more than half solved. The foundation of a good system is laid, at any rate; and it becomes very much a matter of individual preference whether the cartridge shall be used with this or that breech-action. At this moment there are so many good rifles before the public that the difficulty consists rather in deciding which is the best than in deciding whether any one of them will do.

All these systems have a point of contact in the cartridge. They do not all fire identically the same cartridge, although they could, of course, be made to do so; but they all fire a metallic cartridge—a cartridge which forms a gas-check at the breech, and which has to be withdrawn after firing, and either thrown away or re-filled. There are two great classes of cartridges—those which belong to the class above described, the *cartouche obturatrice*, as the French call them, for the reason that they "obturate," or seal the breech at the moment of explosion; secondly, cartridges which are intended to be consumed by the explosion, the arm itself or some portion of the breech mechanism furnishing the gas-check. The English "Boxer" service cartridge, the solid metal cartridge, the stout pasteboard sporting cartridge, are all types of the first class; the Chassepot and needle-gun cartridges are types of the second class. The objections to the second class of cartridges are not inconsiderable. In the first place, the gas-escape being taken by the breech of the gun, continued firing tends to make that check less effectual. In the needle-gun, for example, where there is only a mechanical fit of one metal upon another, the "spitting" of fire at the breech is inconveniently great. The same thing occurred in our own cavalry "Sharp" breech-loaders. In the Chassepot the spitting is prevented by an india-rubber ring or washer, which, however, is liable to become injured by use, or hard with frost, or rotten with heat, and which then, of course, fails to fulfil its object. Indeed, we are informed on credible authority that this defect exhibited itself to a considerable and inconvenient extent during the late war (1870-1). Again, although cartridges of this class are supposed to be con-

sumed by the discharge, it is a fact that they frequently are not altogether consumed—débris collects and fouls the chamber of the gun, and loading, after a time, becomes difficult. Again, if made very thin, these cartridges are liable to be exploded *en masse* by the accidental ignition of one or two cartridges in their midst.

The list of objections could be largely extended; but the three which we have named will suffice to show that the English military authorities are not without reason in having set their face against the "consuming" cartridges, and in having adopted the *cartouche obturatrice* for use with our military rifles. For with an obturating cartridge you renew your gas-check each time of firing; you have a cartridge which cannot be exploded by the adjacent explosion of another cartridge; you have a cartridge far more capable, because stronger, of resisting rough usage, transport, and damp; you have a cartridge which, if a miss-fire occurs, can be withdrawn without the use of the ramrod, by simply applying the ordinary extractor; you have a cartridge, also, which is less liable to miss fire, for the reason that its position in the chamber is always determined accurately by means of the projecting metallic base; while with the paper cartridge the position in the chamber varies according to the exact size of the cartridge and of the chamber, the former being, of course, variable, according as the cartridges become deformed in handling and transport.

All these advantages belong to the class of cartridges of which the English service cartridge—the invention of General Boxer, R.A.—forms the best known and most successful type. In this cartridge the maximum of strength is obtained with the minimum of metal. A pasteboard cartridge is inadmissible for military purposes, because it is liable to swell with damp, and is more or less susceptible to injury in other ways. We are, therefore—having narrowed our selection down to the obturating non-consuming class of cartridges, and having eliminated from this class the pasteboard cartridge—left to choose between a cartridge on the Boxer or coil system, and one on the solid metal system. The latter is much more costly than the former, more metal being used in it, and the loss in manufacture being greater. But it is urged that, as the

cartridge-case is capable of being fired many times, it is, in the end, cheaper than a once-fired Boxer cartridge. To this there are two answers: first, that the operation of collecting and re-filling empty cartridges is not one which can be carried out by soldiers on service; secondly, that the Boxer construction of cartridge is just as suitable for refilling as—if not more so than—the solid metal cartridge. We have ourselves seen these cartridges re-filled and fired as many as thirty-two times. The best authorities are, however, now generally agreed that the operation of re-filling cartridge-cases is not one to be entertained for military purposes, however practicable for sportsmen.

Before proceeding to describe the Boxer, or service cartridge, it may be well to observe in passing that the self-consuming cartridge is not, as is frequently supposed, necessarily cheaper than the metallic cartridge; on the contrary, the Chassepot is a very expensive cartridge, as it is all made by hand. Again, it is generally assumed that loss of time takes place in extracting the empty case of the non-consuming cartridge after firing. This is an error. Even in the Snider the loss of time is inappreciable, and in the improved types of breech-loaders, such as the Martini-Henry, the operation of extracting is combined with that of opening the breech and cocking the arm; there is, therefore, absolutely no loss of time whatever caused by extraction.

The Boxer service cartridge for the Snider rifle (Fig. 5) consists of a case of thin brass, ·005 inch thick, rolled into a cylinder, and covered with paper, by which the coil is cemented together. The coiled case is fitted into a double base-cup of brass, with an iron disc forming the end of the cartridge which abuts against the breech-block of the rifle. The case is secured in its position by means of a rolled paper wad inside, which is squeezed out with great force against the sides of the case. The iron base is attached to the cartridge by means of the copper "cap-chamber," which contains the detonating arrangement; the cap-chamber, being riveted over at each end, holds the base tightly to the cartridge. The ignition is effected by means of a percussion-cap, resting on a small shouldered brass anvil. To explode the cap, it is necessary that the crown of the cap should be indented (by the striker of the

rifle, for example), when the detonating composition is brought into contact with the anvil, and the flash passes through the fire-hole at the bottom of the cap-chamber to the powder in the case. The top of the cartridge is closed by means of a small quantity of wool, over which is fitted

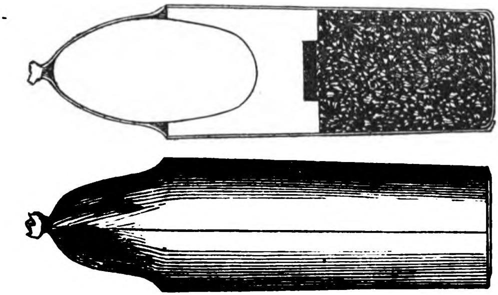


Fig. 6.—AMMUNITION FOR PRUSSIAN NEEDLE-GUN.

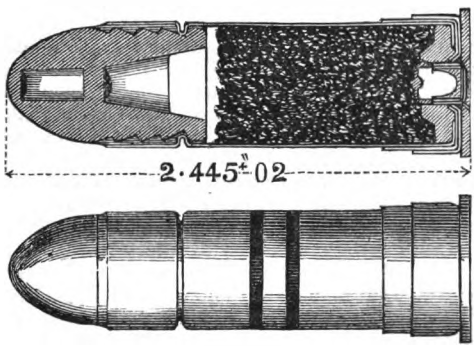


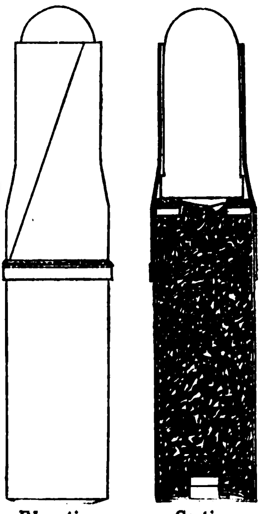
Fig. 5.—BOXER CARTRIDGE FOR SNIDER RIFLE.

the bullet. This bullet has four grooves or *cannelures* round it, which serve to carry the wax lubrication, which in this ammunition is distributed in a thin film around the bullet. The construction of the bullet is peculiar, the head as well as the base being hollowed out. The base

is hollowed out for the same reason as in the bullet for the muzzle-loading Enfield—viz., for the insertion of a clay plug, by which the bullet will be expanded into the grooves of the rifling. The head of the bullet is made hollow, in order to give the necessary length to the bullet without increasing the weight. The following are the details :—Length of bullet, 1·065″; diameter (without lubrication), ·573″; weight, 480 grains. Length of cartridge, 2·445″; weight, 1 oz. 10 drs. 20 grs.; charge, 70 grains. This bullet, although an ingenious contrivance for overcoming the difficulties inherent in a large bore slow-twist rifle, is the least satisfactory part of this ammunition; and repeated changes have been made, and innumerable experiments, with a view to the adoption of another bullet for this arm. Hitherto the results have been attended with little marked success, and all that can be said is that the present bullet gives an accuracy and general shooting power about equal to that of the old Enfield, and superior to it in one respect—viz., that the wounds inflicted by the hollow-headed bullet are much more severe than those inflicted by the solid-headed bullet.

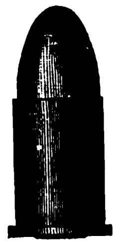
The conversion of our muzzle-loading arms may be said to have fully answered its purpose. Let no one depreciate the Snider rifle. It is an admirable weapon, and, taken all round, superior to most of the breech-loading rifles in the hands of other military powers. It is simple, durable, economical, capable of a rapidity of fire of from twelve to eighteen shots per minute, according to the skill of the firer; the extraction of the empty case is effected with ease and rapidity; the ammunition is exceedingly durable, strong, little susceptible to injury by damp, and as cheap, probably, as any equally serviceable ammunition can be made. It is important to notice that one characteristic feature of great excellence in this cartridge is the coiled case. The action of firing causes the case to expand immediately against the sides of the chamber; and this expansion is followed by an instantaneous contraction, by means of which the withdrawal of the empty shell is greatly facilitated. Also, the arrangement of base is especially noteworthy—the solid end, which gives great stability to a part of the cartridge where strength and

resistance are required, and which likewise serves for the claw of the extractor to take hold of. The double cup affords the necessary strength round the back end of the cartridge, the part upon which the greatest strain comes, especially if the block of the rifle should happen not to fit very accurately, or if, from any other cause, the cartridge should be subjected to undue strain round the rim.

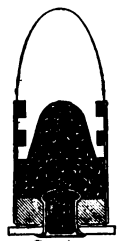


Elevation. *Section.*

Fig. 7.—AMMUNITION FOR FRENCH CHASSEPOT.



Elevation.



Section.

Fig. 8.—BOXER CARTRIDGE FOR BREECH-LOADING REVOLVER.

Having given a drawing of our own service cartridge, we think that the accompanying drawings of the cartridges for the Prussian needle-gun (Fig. 6, p. 27) and the French Chassepot (Fig 7), with the following details as to dimensions, weight, etc., may be of interest for comparison. These are, for Prussian needle-gun :—Length of bullet, 1·08″ ; diameter, ·533″ ; weight, 480 grs. Length of cart-

ridge, 2·44″; weight, 1 oz. 6 drs. 20 grs.; weight of charge, 66 grs. For French Chassepot:—Length of bullet, 1·″; diameter, ·463″; weight, 380 grs. Length of cartridge, 2·64″; weight, 1 oz. 2 drs. 2 grs.; weight of charge, 85 grs.

The needle-gun cartridge is made of paper. Rotation is given to the bullet by means of a paper sabot, which, being slightly larger than the bore, is forced into the rifling. The bullet thus does not touch the bore at all, but is spun by means of the sabot. This method is a clever plan for obtaining the advantages of a large bore, in respect of shortness of cartridge, prompt ignition of the charge, etc., while preserving the advantages of a small bore as far as the bullet is concerned. But the needle-gun is not at all a satisfactory arm, considered as an arm of precision or as a breech-loader. The liability, under the latter head, to escape of gas at the breech, has been before remarked upon; in addition, the mechanism is defective in some important particulars. As an arm of precision, the weapon is feeble. The velocity imparted to the bullet is small—only about 1,000 feet per second, as against 1,390 for the Chassepot, 1,260 for the Snider, and 1,365 for the Martini-Henry; the trajectory is consequently high, the range is small, and the accuracy of the weapon leaves much to be desired—so much, indeed, that we find the Prussians took advantage of the large number of Chassepots which fell into their hands to arm some of their troops with them. But the Chassepot, as we shall see when we compare it hereafter with the Martini-Henry, is far from a satisfactory arm. The ignition of the needle-gun cartridge is effected by means of a small patch of detonating composition placed at the back of the sabot, into which the needle penetrates when the arm is fired.

The Chassepot cartridge is made of thin paper, covered with thin silk, the latter being intended to secure the blowing out of the whole of the débris of the consumed cartridge when the arm is discharged. The ignition is effected by means of a percussion cap, into which the needle strikes, disturbing the detonating composition; the flash passing through holes in the crown of the cap. The cap, it will be observed, is presented to the striker in the

opposite direction to the cap in the Boxer cartridge, and the ignition is effected by means of a needle, instead of with a blunt piston. To prevent the gas from the exploded cap escaping backwards, the mouth of the cap is covered with a thin disc of india-rubber, through which the needle passes. Sometimes this india-rubber comes back with the needle, interfering with its action. This is one of the minor defects of the system. There are several other defects, too numerous to be here enumerated, but to which the French are now only too fully alive.

Other means of igniting breech-loading cartridges have been designed. There is the well-known "pin-fire," so common in sporting cartridges, in which a blunt pin which projects from the cartridge, and one end of which rests in a percussion-cap inside the cartridge, is driven down by the hammer of the gun. There is also the "rim-fire" cartridge, a common American form, in which the fulminate is enclosed in the rim of the base of the cartridge. This method is objectionable on many accounts, and such cartridges are very dangerous to manufacture. Then, of "central-fire" cartridges, of which the Boxer is an example, there are infinite varieties; but the system of cap and anvil is the one most generally in vogue. It is hardly possible to doubt, however, that this detail will in time be considerably simplified and improved upon.

We will mention in this paper one other description of breech-loading cartridge, and one only—namely, the service cartridge for the breech-loading revolver. The construction of this cartridge is sufficiently exhibited in Fig. 8, p. 29. This ammunition has now entirely superseded the old skin or paper revolver cartridge, which was in vogue until a few years ago. The pistol with which it is used in her Majesty's service is an Adams revolver—a simple, strong, quick, serviceable weapon.

CHAPTER V.

BREECH-LOADING SMALL ARMS (*concluded*).

IN a former chapter we have treated of the transition from muzzle-loading to breech-loading rifles for military use, and have shown how this was accomplished in our own service, by the simple and satisfactory expedient of fitting the Enfield rifle with an arrangement which admitted of its being loaded at the breech, and providing it with a suitable and ingenious breech-loading cartridge. The combination gives us an arm about equal to the old Enfield rifle in shooting power, but more destructive, in consequence of the employment of a hollow bullet, and capable of greatly increased rapidity of fire. But it was clear that we had not here the final and complete solution of the question. The shooting power of the old Enfield is not of a sufficiently high character to fully satisfy the requirements of the present age. Since 1853, when this weapon was introduced, vast strides have been made in arms of precision; and the Enfield rifle is now unable to hold its own against the small-bore rifles, which surpass it in accuracy, range, flatness of trajectory, penetrative power, and other valuable qualities. So also with regard to the breech action: many minds have been at work on this question for several years, and the result is that there exis several breech mechanisms which are as superior to the Snider as the small-bore rifle is superior to the large bore.

Therefore, it became a recognised necessity for the military authorities to look beyond their converted Snider-Enfields to a new arm for future manufacture. It would occupy too much space if we were to attempt to describe the steps and experiments which have finally resulted in the adoption of a composite arm—the Martini-Henry rifle. This arm has the form of a barrel designed by Mr. Alexander Henry, of Edinburgh—viz., a polygonal barrel, the angles of which are broken by ribs which create re-entering angles, the inscribing circle tangential to the ribs being described with the same radius as the inscribing circle tangential to the plane sides. The twist of rifling is

1 turn in 22 inches. The calibre is ·45 inch. Admirable results have been obtained with these barrels, which are now very generally adopted by military rifle-makers, who fit on to them different breech-actions, according to their fancy. The initial velocity of the rifle, with a charge of 85 grains, is about 1,365 feet per second, against 1,260 for the Snider; this, taken in conjunction with the fact that the bullets are of the same weight (480 grains), but that the Henry bullet is of less diameter than that of the Snider, results in a considerably flatter trajectory on the part of the Henry bullet, in greater range and in greater accuracy. Also, the Henry bullet is less affected by wind.

What breech-action should be fitted to this barrel to render it a perfect arm? This question has given rise to immense discussion and to innumerable experiments. Mr. Henry himself had a breech-action of great merit, which some persons thought it would be well to employ. But the question was directed to be settled experimentally, and the result of the experiments was that the Henry breech mechanism had to yield the palm to a mechanism designed by Mr. Martini, a naturalised Swiss subject. This action is best described by Figs. 9 and 10, p. 34.

The action consists, as will be observed, of a falling block, hinged upon a pin which passes through its rear end, the recoil being taken by the iron framework at the back. Inside this block is situated the striker, by means of which the cartridge is exploded, and the strong spiral spring, by means of which the striker is actuated. The block is raised and lowered by a lever, which in the act of lowering the block also compresses the spring, thereby bringing the rifle to full cock; and the front end of the block striking smartly upon the bent lever, the extractor ejects the empty cartridge. When the fresh cartridge has been introduced, the block is returned to its place by the return movement of the lever, and the arm is ready for firing; or, if it be not desired to fire it immediately, there is a small safety-bolt, easily manipulated by the fore-finger and thumb, which serves to lock the arm and prevent it from going off. Also, the gun is provided with an "indicator" at the side, to show when it is cocked. The indicator, being attached to the "tumbler," moves with it

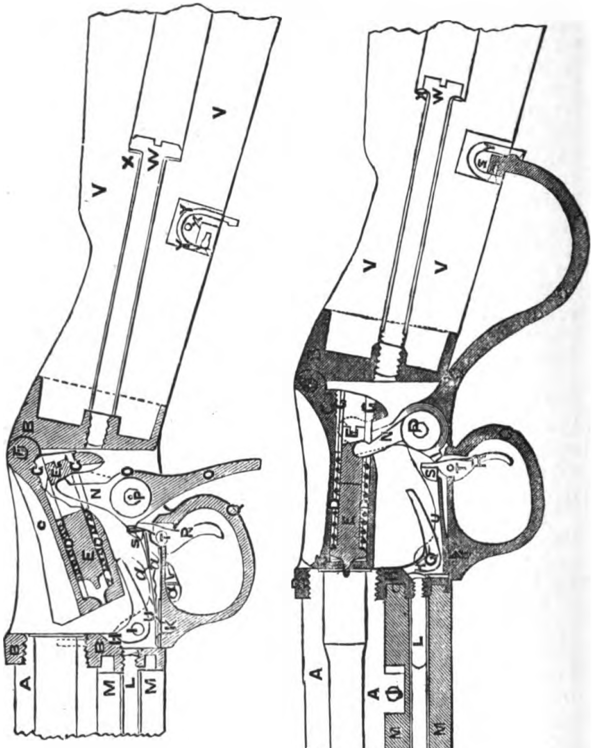


Fig. 9 (*open*). Fig. 10 (*closed*).

SECTION OF BREECH OF MARTINI-HENRY RIFLE.

Refs. to Letters in Figs. 9, 10:—A, barrel; B, body of breech-action; C, block; D, main-spring; E, striker; F, block axis pin; G, stop nut; H, extractor; I, extractor axis pin; J, pin for barrel stud-hole; K, trigger and rest spring screw; L, cleaning rod; M, fore part of stock; N, tumbler; O, lever; P, lever and tumbler axis pin; Q, trigger-plate and guard; R, trigger; S, tumbler rest; T, trigger axis pin; U, trigger and rest spring; V, hind part of stock; W, stock-bolt; X, stock-bolt washer; Y, lever catch-spring; Z, lever catch-block and pin; *a*, locking-bolt; *b*, locking bolt thumb-piece; *c*, thumb-piece screw; *d*, locking bolt-spring.

and parallel to it; and as the arm cannot be cocked unless the tumbler be in a certain position, the indicator shows infallibly its condition.

The tests which the Martini-Henry breech-action has undergone have been extraordinarily severe, although scarcely more so than the criticism to which it has been subjected. This criticism has, however, had this good effect: if it has somewhat interfered with the early adoption of this arm, by rendering necessary continued trials, it has, through these trials, fully established the extraordinary merits of the breech-action. At first the objection was urged that although one or two show specimens, prepared specially for trial, might succeed in satisfying such tests as the Committee were able to impose, the arms if placed in the hands of the troops, would certainly break down. To meet this, 200 Martini-Henry rifles were issued to the troops, who for about a year and a half have had them under trial. The result of these trials, carried on in all climates, from India to Canada, in all weathers, and under all sorts of circumstances, has been to elicit most favourable reports of the arm. Then it was urged that at any rate the arrangements of the breech were mechanically defective; that no mechanical engineer could have any doubt on this point; that a mechanism radically unmechanical could not continue to give reliable and satisfactory results. Accordingly, the evidence was taken of three very eminent mechanical engineers—Professor Pole, Mr. Nasmyth, and Mr. Woods. These gentlemen, instead of pronouncing a condemnation of the mechanism, declared that it is an excellent piece of work, and passed high encomiums on its simplicity, strength, and efficiency. The criticism that as the recoil is taken by the breech axis pin, that pin must necessarily wear away or break in time, they met by the statement that the recoil is not taken by the pin at all, but by the socket behind the block, whence it is transmitted throughout the whole system of the rifle, the weight of which is thus brought to resist it; and this statement they supported by reference to a very simple experiment, in which the block axis pin had been replaced by one of lead, on which no mark of any recoil was perceptible. In another instance the gun was worked perfectly without any

pin at all. The spiral spring has been a prominent point of attack. It has constituted, so to speak, the citadel of the system, and against it all the main efforts of the opponents of the arm have been directed. One inventor of a rival breech-action based his claim mainly on the substitution in his system of a flat for a spiral spring. This objection the mechanical engineers met very decidedly. For the purpose of which it is required in this gun—viz., to cause a striker to impinge directly upon the percussion-cap of a breech-loading cartridge—they greatly preferred the spiral to the flat spring. It is far cheaper—as a halfpenny to sixteen-pence—it admits of a far more compact arrangement of parts; it is, notwithstanding all that has been said to the contrary, quite as reliable as a flat spring—a point which they supported by quoting various well-known applications of spiral springs; it is quite as easy to make in large quantities and of uniform quality; and as for the statement that the spiral spring gives more of a push than a blow, one witness showed mathematically that the blow which is struck by the spiral spring in the Martini-Henry is really a quicker, smarter blow than is struck by the hammer of the Snider. As to the merits generally of the spiral spring—the point which inventors of other systems have declared to be fatal to the Martini—all the mechanical witnesses agreed in pronouncing it thoroughly mechanical, sound, and reliable. Then it has been objected that the divided stock is weaker than the ordinary gun-stock. Not so, say the engineers; it is rather stronger; and if desired it can be made stronger still. Nor is this mere theory. They appealed to the results of an experiment which was carried out at Enfield in their presence to test this point. And so, before the independent testimony of thoroughly competent, indeed, distinguished witnesses, the criticisms which have been freely indulged in by those who have rifles of their own which they would prefer to see introduced, have melted away. Whether the criticism will therefore cease it is not easy to say; possibly it will not. But the readers of this manual at any rate will have the assurance that the future arm of the British soldier, whatever may be said about it, has undergone tests and trials to which no other weapon was ever submitted; that it has passed one ordeal after another not merely satisfac-

torily, but triumphantly—the ordeal of the rigorous trials which were instituted by Lieut.-Colonel Fletcher's committee, the ordeal of knocking about and handling by the troops, the ordeal of public trials at Wimbledon, where the arm has carried off the greater part of the more important breech-loading prizes; the ordeal of public criticism; finally, the ordeal of a minute scrutiny at the hands of professional mechanics. If an arm can stand all this, and come out unscathed, as the Martini-Henry has done, it is surely a fit arm to put into the hands of our troops. This, then, is the future weapon of the British soldier—the Martini breech allied to the Henry barrel.

The cartridge to be used with this arm is the Boxer, but of a form different from that in use with the Snider. The first cartridges made for the Martini were very long, the small diameter of the barrel and the large charge of powder rendering necessary this length so long as the cylindrical form of cartridge was retained. To this cartridge objections were made on account of its length. Accordingly the form was modified, the substantial features of the Boxer construction being retained. In the modified cartridge the body is enlarged in diameter, and tapered down at the fore-part to the diameter of the bullet. The outline of the cartridge is thus that of a long-necked bottle, whence the name by which it is frequently known, the "bottle-neck" cartridge. A drawing of this "short-chamber" cartridge, as it is officially designated, shows the details of the construction, and it will be observed, on a comparison of this drawing with that given in a former chapter of the Boxer cartridge for the Snider, that the construction of the two cartridges is practically the same. There is the thin coil-case, the iron disc base, the strengthening cup, the papier-maché wad by which the parts are held together, the cap and anvil arrangement for ignition.

But the fore-part of the cartridge is different; the mode of lubricating is different; the bullet (which is Mr. Henry's) is different; the cartridge is not covered with paper; and the base is strengthened by means of the insertion of a piece of metal between the folds of the brass, thereby obviating the necessity for additional strengthening cups. A few words may be said with

regard to the bullet and lubrication. The bullet is solid, with the exception of a shallow cavity in the base, into which the folds of the paper which envelops the bullet are inserted. At its back end, the bullet is of the same diameter as the bore, viz., ·45 inches. It tapers slightly,

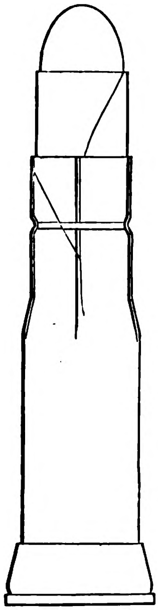


Fig. 11.—*Elevation.*

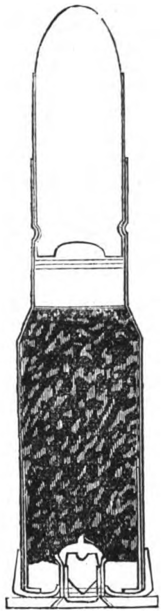


Fig. 12.—*Section.*

BOXER-HENRY CARTRIDGE.

until at the shoulder the diameter is only ·439 inches. In a former chapter it has been explained that the main feature of the bullet for the original muzzle-loading Minié and Enfield rifles consisted in the arrangement by which the bullet was expanded into the rifling, by the explosion

of the charge acting upon an iron cup, or a wooden plug in a hollow at the base. Thus the bullet entered the rifle fitting loosely, and left it fitting tightly. In a breech-loader, however, there is no necessity for having a bullet which will enter the barrel easily, as it is generally introduced into a chamber at the breech end, and may be made in the first instance of the full requisite diameter. We have seen, however, that Colonel Boxer in his bullet for the Snider did retain the plug expansion, with a view partly to getting the requisite length of bullet in a large-bore rifle without any undue increase of weight. But in the Henry rifle no such device is necessary, and Mr. Henry therefore made his bullet of the full diameter of ·45 inch, depending upon such slight enlargement as the bullet received by the opposition of its own inertia to the shock or discharge, to take up the rifling. The action of Mr. Henry's bullet, therefore, depends upon what is known as the "overtaking" principle, the back end of the bullet slightly overtaking the fore end, owing to the inertia of the mass in front, and thereby setting up, and expanding the bullet into the grooves.

The lubrication of this rifle is effected by means of a cylindrical wad of pure beeswax, placed behind the bullet, and enclosed in discs of jute cardboard, to prevent it from sticking either to the bullet or to the powder. This wad was originally made solid, but it was found not to act perfectly in very cold weather, and it was therefore thickened and hollowed out in front, thus giving more space for the powder to act through and less work for it to do. The wad is squeezed between the exploded powder charge and the bullet, and just as the bullet is set up and enlarged, so the wax wad is set up and enlarged, although of course to a far greater extent, and as it is driven through the bore, it lubricates it effectually.

It remains now only for us to say a few words with regard to the powers of the Martini-Henry rifle, using the ammunition above described. The accuracy of shooting of the arm is remarkably great. The following facts, extracted from official records, are satisfactory upon this point. At 300 yards, the mean radial deviation of 20 shots fired from a fixed rest, has been as good as ·47 feet; at 500 yards, ·79 feet; at 800 yards, 1·29 feet; at 1,000

yards, 2·19 feet; at 1,200 yards, 2·28 feet. Perhaps these figures will scarcely convey to all our readers the impression which they would make upon the mind of any one who is familiar with the mode of estimating "figures of merit" in rifle-shooting, namely, to find out by calculation the centre of each group of 20 shots, and to find the mean distances of these shots from this centre. Obviously, the smaller this distance, the smaller the limits of the group, and the more accurate the shooting. When a trial was recently made between the Snider, the Chassepot, and the Martini-Henry, the following results were obtained:—

	MARTINI-HENRY.	SNIDER.	CHASSEPOT.
500 yds. . .	·815 feet.	1·47 feet.	2·77 feet.
800 " . .	1·57 "	3·78 "	5·22 "
1,000 " . .	3·66 "	8·34 "	13·08 "

Putting this into a popular form of expression, it means that if we take the Martini-Henry as a standard as equal to 100, we have the following comparison:—

		At 500 yds.	At 800 yds.	At 1,000 yds.
Snider	=	55·4	41·5	43·9
Chassepot	=	29·4	30·0	28·0

Or, expressing it more roughly still, we have the following tabular comparison of the performances of the rifles, namely:—

	At 500 yds.	At 800 yds.	At 1,000 yds.
Martini-Henry to Snider, as about	2 to 1	2½ to 1	2¼ to 1
Chassepot " " "	3 to 1	3 to 1	3 to 1

Let us now turn to the trajectory of the arm. It is obvious that the flatter an arm shoots—in other words, the lower the trajectory is—the more ground will the bullet cover in its flight. The greatest height of the trajectory of the Snider is 11·9 feet in 500 yards; the Martini-Henry only 8·9 feet. The practical effect of this is that, supposing two men to be firing, lying on the ground, and aiming at the feet of a body of troops 500 yards distant, a body of infantry might safely cross the Snider range anywhere between 92 and 438 yards, the bullets flying over their heads; while in only from 139 to 396 yards would they be safe in the Martini-Henry range; and as for cavalry, while on the Snider range from 138 up to 400 yards they

would be safe, there would on the Martini-Henry range be no spot which a cavalry soldier could pass in safety. Beyond 500 yards the advantage of the Martini-Henry rifle in respect of trajectory would be increasingly greater.

The next point is initial velocity—the velocity, that is to say, at which the bullet leaves the muzzle. This is as follows:—

Martini-Henry	1,365	feet per second.
Chassepot	1,391	"
Snider	1,262	"

It will be observed that the Chassepot bullet has a slightly higher initial velocity than the Martini-Henry, but the bullet being lighter (380 against 480 grains) it has less power to overcome the resistance of the air, and therefore soon loses this high velocity. At 150 yards from the muzzle, or even at a less distance, the Martini-Henry bullet will be travelling with a velocity equal to that of the Chassepot, and from that point forward the latter will gradually be losing in the race.

The effect of this high velocity, combined with a good weight and a small diameter, is to give the Martini-Henry bullet great penetrative power, as well as that low trajectory which has been spoken of. It has been found by experiment that the bullet will penetrate as follows:—14½ half-inch elm planks at 100 yards; 3 three-inch fir balks dry, in addition to 1 wet, at the same distance; 1 plate of ·261 inch iron at 200 yards: 4 thicknesses of 3-inch rope at 350 yards; a gabion filled with clay earth at 25 yards; a sap roller at 25 yards; a sand-bag at 100 yards.

While the normal accuracy of the Martini-Henry rifle is far greater than that of the Chassepot and Snider, and enormously superior to that of the needle-gun, which is by far the worst arm of the four, the Martini-Henry bullet is less affected by wind—a great advantage to the marksman. The cartridge is stronger and better than that of the Chassepot. The rapidity of fire is more than double: thus, at an official trial—

The Chassepot fired	20 rounds in	1	minute	42	seconds
The Martini-Henry	"	0	"	48	"

Thus in seven points—namely, (1) increased strength and safety of ammunition, (2) greater accuracy, (3) longer range, (4) flatter trajectory, (5) higher penetrative power, (6) greater safety, strength, and simplicity of construction, (7) increased rapidity of fire—the Martini-Henry is superior to the Chassepot. It is also, although in a less degree, superior to the Snider on most of these points. Such is the weapon with which the British soldier will in future be armed.

This brings to a close our remarks on Small Arms. We shall now pass to the subject of Gunpowder, and thence to that of Great Guns.

CHAPTER VI.

GUNPOWDER.

THE powder used for the charges of guns and small arms necessarily influences in a great degree the efficiency of the weapons. There is no direction in which English artillerymen have laboured so determinedly, and, on the whole, successfully, as in the direction of the improvement of the powder for guns and small arms. For the moment we are engaged with small arms only; but it will, perhaps, be convenient if we deal with the subject of powder as a whole, and take this occasion to speak generally of the different descriptions of gunpowder in use in the British service.

Gunpowder, as all the world knows, is an intimate mixture of saltpetre, sulphur, and charcoal.

The proportions of the ingredients differ in various countries. The following table, extracted from Captain Goodenough's "Notes on Gunpowder, Prepared for the Use of the Gentlemen Cadets," shows the rates, or percentage, of the several ingredients in the powder of different countries:—

	Saltpetre.	Sulphur.	Charcoal.
England (Government powder)	75	10	15
France, Prussia, United States	75	12·5	12·5
Russia	73·78	12·63	13·59
Austria	76	12·5	11·5
Spain	76·47	12·75	10·78
Sweden	75	16	9
China	75	14·4	9·6
Switzerland	76	14	10

English powder has long held almost undisputed supremacy as to excellence of quality and strength. The purity of the ingredients employed, and the elaborate care which is bestowed upon all the processes of manufacture, result in the production of an explosive and propellant agent of great power. Indeed, the chief objection to the English powder has been that it is too strong. We believe that we may safely affirm that there is no powder in the world equal to that which is produced at the Government mills at Waltham Abbey, unless it be the powder which is turned out from the mills of some of the leading English makers, such as Curtis and Harvey, Hall and Sons, Pigou and Wilks, and others.

The action of gunpowder is due to the almost instantaneous decomposition of the saltpetre by the charcoal, the latter being burned by the oxygen of the saltpetre, with which it combines in the act of burning to form carbonic acid gas. At the same time the oxygen in the saltpetre becomes separated from the nitrogen with which it was combined.

The explosive force of gunpowder is mainly due to the sudden evolution at a high temperature of these two gases —carbonic acid and nitrogen. In this action, it will be observed, the sulphur plays apparently no part. Indeed, it is a fact that gunpowder may be made without sulphur at all; but the explosive force of a mixture of saltpetre and charcoal is comparatively feeble, because the evolution of the gases in such a mixture is very slow, and the temperature of the gases, and the consequent expansion, relatively small. Sulphur, therefore, which ignites at a much lower temperature than either of the other two

ingredients, is added to render the action more rapid, and, by raising the temperature of the gases, to increase their expansive power. Sulphur also increases the volume of the gas, by combining with the potassium in the saltpetre, and so liberating the oxygen with which that potassium was combined, the liberated oxygen becoming available for the burning of the charcoal.

It is to the presence of the sulphur that we owe the white smoke and the solid residue of fired gunpowder. The smoke and residue are chiefly sulphate of potassa (K_2SO_4) and carbonate of potassa (K_2CO_3), resulting from the combination of the sulphur with the potassium. Some of the sulphide of potassium is carried out by the escaping gases, when it catches fire and burns—forming flash and smoke; that portion of it which is not carried out being left in the form of a solid residue.

The explosion of a charge of gunpowder can be effected by raising a single grain of the powder to a temperature of about 600°, which is about the temperature at which the sulphur sublimes. When one grain is ignited, the resulting gases are transmitted by their own expansive power through the interstices, igniting other grains, and finally consuming the whole charge. From this it follows that the ignition of a charge of gunpowder is not necessarily—indeed, it is not under any circumstances—really instantaneous. Gunpowder, in fact, burns, but the combustion generally takes place at so great a rate that it practically amounts to, and is generally spoken of as, instantaneous ignition. This consideration brings us to a very important branch of our subject.

Those who have followed us thus far will have recognised that the explosive force of gunpowder is not determined alone by the amount of gas developed. It depends upon three main causes: the amount of gas developed; the heat evolved, by which the expansion of the gases is influenced; and the rapidity with which the gases are produced. As to the first two points, we have said all that is necessary for present purposes. As to the third point, it is clear that if the rapidity of the inflammation of the charge depend, *cæteris paribus*, upon the rapidity with which each grain successively becomes ignited and consumed, it is possible largely to

influence the action of the powder by altering the size and shape of the grains.

Thus, for example, to put an extreme case: if the powder were not disposed in grains at all, but existed in the form of a solid mass, like what is technically known as "press cake," the inflammation of the mass would be very slow indeed; the flame applied to one portion would flash over the whole surface, and then proceed to consume the mass from outside to within, burning it slowly away in successive layers. If the mass, however, be broken up into an infinite number of small particles, the effect is to open a large number of passages through which the gases at once rush, thus practically igniting each grain in the same instant of time; and in proportion as the individual grains are of a size and shape which permit of their being readily consumed, so will the burning of the whole mass of powder, and consequently its conversion into gases, be rapidly effected.

Here we have the two extremes—of slow and rapid ignition; extremes which are susceptible of modification at will, and between which lie the various applications which the artillerist makes use of. In short, it comes to this, that the action of gunpowder can be largely influenced by mechanical means, and without prejudice to its chemical character. Of course, the chemical character can be influenced by a change in the proportion of the ingredients, in their purity, in the mode of manufacture, etc.; but obviously the better course is first to discover, by theory and practice, the best chemical constitution for gunpowder—that constitution which is capable of producing the maximum results from the three ingredients of which gunpowder is composed—and then to seek mechanically to control the violence or rapidity of the action. In practice, this is what we do in England, and the field of experimental inquiry thus opened out is exceedingly wide.

One interesting application of this theory is that which was proposed by Mr. Gale, the well-known experimentist, of Plymouth. Mr. Gale, following—although perhaps unconsciously—the steps of the French artillerist, Piobert, and those of the Russian chemist, Fadéieff, filled up the interstices of gunpowder with an inexplosive substance,

such as finely-powdered glass, and in this way, by cutting off communication between one grain and another, made the powder absolutely inexplosive. Mr. Gale proposed to dilute all powder in store with the ground-glass, and when required for use to sift out the glass, when the powder would resume its natural explosiveness. The idea was ingenious, but it was open to many practical objections, which, in spite of the success that, on the whole, attended the long series of costly experiments which were made, ultimately determined the rejection of the proposition, although at first sight it appeared to many to be feasible enough.

More useful advantage is taken of the fact that the explosive violence of gunpowder can be readily controlled by mechanical means, in connection with the adoption for the different natures of fire-arms of the powder most suited to them. The size of the charge, the nature of the work required to be done, and the reduction of the strain upon the weapon, are the three considerations which mainly influence the determination of the most suitable powder. A few words upon each of these points in succession may be useful.

1. *The size of the charge.*—It might be hastily assumed that the size of the charge could not have much influence upon the nature of the combustion, and therefore could not affect the selection of the powder for particular arms. The popular notion would probably be—that if a powder, of a particular size and form of grain and density, burn quicker than another powder in *any* fire-arm, it must burn quicker in *all* arms. And this argument would probably go forward to the conclusion that fine-grain powder must, under all circumstances, burn quicker than large grain. Both these opinions would be erroneous. The rapidity of action of gunpowder depends upon (*a*) the rate of burning of each grain, called the "velocity of combustion;" and (*b*) the rate at which the grains successively become ignited, called the "velocity of ignition." In the case of an open train of powder, the velocity of ignition is independent of the interstices between the grains—the flash travels over and along the train, not through it. So also with small enclosed charges. When the distance which the flame has to traverse is inconsiderable the velocity of

ignition is an element of subordinate importance to the velocity of combustion. In the case of very large charges, however, it is otherwise: the velocity of ignition then becomes a more important element. Consequently, according to the size of the charge, those elements which favour velocity of ignition will have a varying importance, and thus it is impossible to predicate from the size and shape of the grain—which are the elements that mainly influence the velocity of ignition — whether a certain powder will be quick or slow. Other conditions being the same, a fine-grain powder will generally burn quicker than a large grain, except in very large charges, where a very fine-grain powder will not burn so quickly as the same powder disposed in larger pieces.

2. *The nature of the work to be done* bears, of course, directly upon the selection of powder. Thus, in a smooth-bore musket the chief point is rapidity of action; while, with rifled small arms, regularity of combustion and uniformity of action are of greater importance. Indeed, a very quick powder is unsuited for rifled small arms. In the case of an expanding bullet, such as is used in the Enfield rifle, and which was described in Chapter II., it is desirable to make the pressure upon the plug as little of a blow as possible; hence a comparatively slow action is preferred. And in the case of arms firing non-expanding bullets, such as the Martini-Henry, too rapid a powder, by escaping over the bullet, tends to cause fouling. Therefore, we find that the powder which was used for the old smooth-bore arms, and which was known as "fine grain," was of a size to be retained upon a sieve of 36 meshes to the inch, and to pass through one of 16 meshes. The powder used for the Enfield rifle is of a size to be retained upon a sieve of 20 meshes to the inch, and to pass through one of 12 meshes. The powder for the Enfield rifle is, however, different from the old smooth-bore powder in other respects than size of grain. It is made of dogwood instead of alder charcoal, the ingredients are more thoroughly incorporated, the density is rather less, and the grains are more rounded, more uniform in form, and more highly glazed. Again, as an example of the adaptation of powder to the work to be done, may be instanced the use of an exceedingly quick

powder for the bursting charges of Shrapnel shell, where the powder is required to effect the rupture of the shell and the release of the bullets as instantaneously as possible, so as to diminish the possibility of the charge acting upon the balls. Finally, in the case of all rifled guns, it is necessary to select as uniform a powder as possible, and for rifled guns a special powder has generally been employed.

3. *The reduction of the strain upon the weapon.*—When we have to deal with large guns, we are met by the third consideration which we have named, viz., the importance of reducing the strain upon the gun as much as possible. In the use of small arms this consideration may be ignored. The strength of the barrel is largely in excess of what is requisite to resist the explosion of the regulated charge of gunpowder, however rapid in its action; and the same holds good with regard to field-guns and guns of moderate calibre. But it is far different when passing from weapons which fire only 70 or 80 grains of powder, or guns which fire only a few pounds, we get to weapons which consume 40, 60, and 100 pounds of powder at each discharge. The great 35-ton guns built at Woolwich fire 120 pounds of powder—that is, about a barrel and a quarter each. With such charges as these it is necessary to modify the action as much as possible; it is desirable at the same time to do this without diminishing the power of the gun by any reduction in the strength of the powder. This is a problem which has each year become of increasing importance, as the guns and charges have become larger and the strain more severe. It is a problem which accordingly has actively occupied the attention of artillerists for the last ten years. The strain which the gun suffers from most is the violent initial strain at the moment of the first ignition of the charge. If the development of gas be intensely sudden, we have a violent local effect, an expression of irresistible force upon the sides and end of the bore before the shot is moved. A familiar experiment illustrates this. If a charge of powder be placed in a thin glass tube, and a charge of fulminating mercury—which, compared with gunpowder, is intensely sudden and violent in its action—be placed in another; and if the two tubes be closed with a cork, and their respective charges ex-

ploded, the cork will be blown out of the tube which contains the gunpowder, while the tube which contains the fulminate will be shattered to pieces. What we require in a gun is, not to burst it, but to blow out the shot. It is desirable, therefore, with very heavy charges, to modify the action of the powder, and this without altering its chemical character and strength. Accordingly, the size and shape of the grains, the density, and the degree of glazing imparted to them—physical conditions which all affect the rate of explosion—are modified in such a way as to make the explosion less rapid, and to distribute the pressure more evenly through the bore.

With this view the Russians, Prussians, and others employ what is called "prismatic powder"—powder which is compressed into hexagonal prisms, perforated to allow of the passage of the gases. This powder is, no doubt, a great improvement upon the granulated powders; but in England it has been found inferior to both "pellet" and "pebble" powders. "Pellet" powder was adopted provisionally in 1866 for use in very heavy charges. It consists of cylindrical pellets instead of grains—the diameter of the pellets being three-fourths of an inch, and their thickness about half an inch. Latterly, a special committee has recommended the adoption of a powder, which, from its representing in form and dimensions large pebbles of the size of the top of a man's thumb, has received the name of "pebble" powder. This powder has lately been adopted for use with the heavier rifled guns. Not merely does the use of this powder greatly decrease the local strain upon the breech end of the gun, being far more gradual in ignition; but it is capable of imparting, with a reduced strain, a far higher velocity to the projectile. Thus, not only is the power of our guns greatly increased, but their time of service is prolonged in proportion to the diminished strain imposed upon them. The uniformity of action of this powder is also greater than that of the ordinary, old-fashioned cannon powder.

The maximum pressure exerted upon an 8-inch gun with 35 pounds of pebble powder is estimated at 15·4 tons per inch, as against 29·8 tons exerted by the former cannon powder ("rifle large grain"), and the initial velocity of the

projectile has been increased from 1,363 to 1,410 feet per second.

It appears, then, that while the chemical constitution of all English powder is practically the same, the physical characteristics of different powders differ widely, the size of grain ranging from the fine "pistol" powder, of which the grains are retained upon a sieve of 72 meshes to the inch and pass through one of 44, up to the leviathan "pebble" powder, of which the lumps (for they are hardly to be called grains) are retained between sieves of $\frac{5}{8}$ and $\frac{4}{8}$ inch meshes respectively. There is no more important subject to the artillerist and the rifleman than that of powder. It has been appropriately called "the soul of artillery." So comprehensive and difficult a subject cannot be exhaustively discussed in a single chapter and the foregoing remarks make no pretensions to an exhaustive character. They merely furnish a slight sketch of the more marked features of a very great and interesting subject.

CHAPTER VII.

GREAT GUNS AND THEIR PROJECTILES.—SMOOTH-BORES.

We now enter upon another stage of our subject. We have dealt hitherto with hand-weapons—weapons to be wielded by individual combatants, and comprised within the term "small arms." We have traced, however imperfectly, the gradual development of weapons of this sort, through the stages of swords, spears, and pikes, of arrows, javelins, and missile weapons, up to the needle-gun, the Chassepot, the Snider, and the Martini-Henry.

We must now turn to great guns, and consider the principal types of cannon in use in this and foreign countries.

The same principles which have governed the successive developments of small arms have applied to cannon, with some modifications or additions. The power of being able to reach your enemy at a continually increasing distance, of being able to strike him with greater and greater certainty, of being able to do him more and more harm, and of accomplishing all this with the minimum of inconvenience and difficulty to oneself—this is the problem which for several centuries the artillerist has set himself to solve; and these conditions may be said to apply to all classes of ordnance, heavy and light. But the conditions imposed in the two cases are very different. In the case of the light gun, the object generally is to destroy men; in the case of the heavy gun, although the ultimate object is to carry destruction and dismay among the *personnel* of your enemy, that object can generally only be attained through the destruction of his *matériel*. Again, while there is practically hardly any limit to the size of the heavy gun, except the endurance of the weapon itself, the field-gun has to be of a weight no greater than will permit of its easy and rapid transport on a campaign, and from one part of a field to another. Lieut. Hime, R.A., in an interesting paper on Field Artillery, in the *Proceedings of the Royal Artillery Institution*, observes that "motion is the essential difference between the two great branches of the artillery service, being as necessarily included in the conception of field artillery, as it is necessarily excluded from the notion of garrison artillery. The latter is the artillery of rest, the former is the artillery of motion; and an immovable field artillery is a contradiction in terms." Marshal Marmont used to say, "Le premier mérite de l'artillerie, après la bravourie des canoniers et la justesse du tir, c'est la mobilité." It would seem that this proposition might be fitly reversed—for no amount of gallantry, no amount of accuracy, would compensate for an absence of mobility. Gustavus Adolphus, at any rate, acted upon this principle, for, as Lieut. Hime tells us, he resolved at the commencement of the Thirty Years' War to increase the mobility of his field artillery "at all hazards," and he actually took the extraordinary step of introducing *leather* guns of great mobility, but of inferior accuracy as compared with the iron guns then in vogue.

These leather guns did good service before they dropped into disuse.

Therefore, it is important to insist upon this fundamental distinction between field and garrison (or naval) artillery —the necessary mobility of the former.

But it would not do to divide artillery into two great groups, separated by a hard and fast line. On the contrary—while in the one direction field artillery shades off into mountain artillery, and garrison artillery developes into the monster turret guns, which are moved on huge turn-tables within the cupola or turret—the two classes of field and garrison meet on common ground, and almost imperceptibly shade off one into the other in guns of position and siege guns.

If we were required to classify artillery at all, we should adopt some such distribution as the following :—

1. Mountain guns.
2. Field guns. { (a) Horse artillery. (b) Field artillery { Light. Heavy.
3. Guns of position.
4. Siege guns.
5. Garrison and broadside guns.
6. Turret guns.

Most of these classes admit of further subdivision—for there are mortars, howitzers, carronades, shell-guns, and guns proper ; there are also smooth-bore and rifled guns. It is evident, therefore, that an exhaustive treatment of every detail of this large subject is impossible within the limits of the present volume. We shall therefore not attempt to deal with each subdivision or class of weapon in detail, but will take the more salient points of the different systems in the order in which they occur to us.

Until about twelve years ago nearly all artillery consisted of smooth-bores. Rifled guns of great variety and ingenuity of design have been prepared by sanguine inventors, and many of them have been experimented with. But the guns of the English service, like those of other nations, remained smooth-bores. It may be supposed that it is unnecessary to speak of smooth-bores now—that their day has gone by so completely as to invest them with no other than an antiquarian interest, This is not the case; it must take many years before

smooth-bores disappear from our service ; for some purposes—as for the flank defence of ditches, where range and accuracy are of no importance, while a high velocity of projectile is of very great importance—smooth-bores will probably always be retained. Again, at this moment there does not exist a single rifled mortar in the British service ; and the Americans scarcely use any other than smooth-bore guns, even for their first-class armaments. So that, although the day of rifled-guns dawned some dozen years ago, that of smooth-bores, although it has passed its meridian, has not yet set.

A smooth-bore gun is merely a hollow tube of iron, or steel, or bronze, or other suitable material, intended to project a spherical projectile. The expression "smooth-bore" has reference, of course, to the unrifled condition of the bore.

The largest smooth-bore gun in the British service prior to 1858 was the 68-pounder, so-called because the solid spherical shot which was discharged from it weighed 68 pounds. The gun itself weighed 95 cwt.,* and it fired a charge of 16 pounds of powder. It is interesting to compare this, the biggest English gun of 1858,† with the biggest English gun of 1871. The latter is a 700-pounder,‡ its weight is 35 tons, or 700 cwt., or more than ten times that of the 68-pounder. The charge of the 35-ton gun will be 110 lb. or 120 lb. of powder. Before we come to speak more particularly of the 35-ton gun, we have a great deal of ground to cover. But it seemed interesting to show by this contrast the strides which have been made in twelve years. All the heavy English smooth-bore guns were made of cast iron—about as bad a material as could well be employed for ordnance, because of its comparatively low resisting power and its liability to yield suddenly and without warning, and thus to cause what artillerymen most dread—an explosive burst. However, for firing the comparatively low charges then in vogue, the cast iron was fairly suitable. It is true that the annals of our artillery are darkened by the record of

* There were some special guns of 112 cwt.

† A few 150-pounder and 100-pounder smooth-bore guns were subsequently introduced.

‡ See Frontispiece.

many disasters due to the bursting of these guns; but it is probable that, had it not been for the introduction of rifled artillery, and the new conditions imposed upon the gunmaker, cast iron would have continued to be employed for several years to come.

Where great lightness was required—as for field-guns—bronze or "gun-metal" was employed. Bronze is an alloy of copper and tin in the proportion of about 11 to 1. The advantages of this material are its lightness, its non-liability to explosive rupture, its value as old metal when the gun is worn out, and the facilities of production. On the other hand, the softness of bronze has always constituted an objection to its use for artillery; this softness was apt to cause the guns to become bulged and unserviceable with long-continued firing, and "drooping at the muzzle" was a complaint to which bronze guns were considered to have been especially liable.

The smooth-bore field-guns of the British service were generally 9-pounder guns and 24-pounder howitzers for field batteries, and 6-pounder guns and 12-pounder howitzers for horse artillery. The howitzers differed from the guns in throwing heavier projectiles with greatly reduced charges. While the relation of the charge to the projectiles in the guns was about as 1 to 3½ or 4, in the howitzers the relation was about as 1 to 9 or 10. This reduction of charge enabled the howitzers, although firing far heavier projectiles, to be made thinner and shorter than other guns, which they thus did not exceed in weight—the 9-pounder gun and the 24-pounder howitzer weighing each about 13 cwt., the 6-pounder gun and 12-pounder howitzer weighing each about 6 cwt.

Between the field-guns and the 68-pounder before mentioned, there were a number of guns intended for a variety of purposes. The designation of these guns was as follows:—56-pounder, 42-pounder, 32-pounder, 24-pounder, 18-pounder, and 12-pounder. The 56-pounder and 42-pounder are fast becoming obsolete, but the other guns still exist in the service in considerable numbers. The whole of these guns were made of a weight and strength which permitted of the use of solid shot or shell, with relatively heavy charges of powder. There were, however, guns intended specially for projecting shell with low

charges; these were the 10-inch and 8-inch shell-guns and howitzers.* There were also pieces designed for projecting either shell or shot with very low charges; these were called carronades. The charges for shell-guns and howitzers varied from about $\frac{1}{6}$th to $\frac{1}{12}$th the weight of the heaviest projectile; the charges for all carronades being fixed at about $\frac{1}{12}$th the weight of the shot.

Originally, shells were not projected from guns and howitzers at all; they were thrown from mortars. A mortar is a short piece for throwing shells at an angle of 45° into an enemy's position; and for the bombardment of a town, or any large area, this "vertical fire," as it is called, is terribly effective. Indeed, it would be terribly effective against all positions, if sufficient accuracy could be obtained to insure hitting the object aimed at. But the comparative inaccuracy of vertical fire—the shell describing a roundabout path to arrive at its object, and being therefore for a longer time under disturbing influences than the shell from a gun—has hitherto constituted a formidable objection to its extended use. It will be easily understood that the effect of a shell falling on to the deck of a ship would be tremendous; but a ship, especially a ship in motion, presents such a small and difficult object for attack, as to entail an immense waste of ammunition in trying to hit it. The same objection does not apply to the employment of mortars against large entrenched positions, towns, etc. Attempts are now being made to introduce rifled mortars, by which the irregularities of vertical fire may be, if not removed, at least diminished, while in range and general power such pieces would be vastly more effective than smooth-bore mortars. An interesting development of mortar-fire was suggested by Mr. Mallet, C.E., in 1858. Mr. Mallet proposed to throw enormous shells, 36 inches in diameter, weighing 2,481 lb., and containing each a bursting charge of 480 lb. (equal to nearly five barrels) of powder. Thus, the total weight of each shell filled was about $1\frac{1}{4}$ tons. Mr. Mallet also proposed a mortar of suitable proportions to project these monster shells. The proposition attracted a good deal of attention, and by Lord Palmerston's order two of

* The number of inches, whence these guns have their designation, refer to the diameter of the bore.

the mortars and a number of the shells were supplied by Mr. Mallet for experiment. Both mortars and shells may be seen by visitors to Woolwich Arsenal, where they form objects of curiosity and interest. Mortars are designated by their calibres in inches. There are five sizes in the British service—viz., 13-inch, 10-inch, 8-inch, 5½-inch, and 4⅖-inch.

We see, then, that there existed smooth-bore ordnance suitable for throwing projectiles of all sorts, and of delivering a "horizontal" or a "vertical" fire; that these pieces were made of cast iron, except those intended for field-guns, which, on account mainly of their greater lightness, were made of bronze. But a gun, after all, is only a means to the end. It is an instrument merely for throwing projectiles, with more or less of range and accuracy—more or less of destructive effect. We will therefore pass to the projectiles which were used with these pieces, before going on to state in what manner the range and accuracy of the smooth-bore guns have been improved upon, and how artillery has attained to the pitch of accurate destructive power which it has now reached. We will therefore proceed to treat of the different classes of projectiles which are fired from smooth-bore guns.

With the exception of such projectiles as were intended to break up at the muzzle and produce an immediate scattering effect, or projectiles which, like the ground light ball, were not required to have any special accuracy, the projectiles thrown from smooth-bore guns were all spherical, that form being the one which naturally, in the absence of rifling, could be thrown with more certainty and accuracy, and to a greater distance than any other. The two main classes of projectiles are shot and shell. There is a third class of incendiary and miscellaneous projectiles which must not pass unnoticed. The varieties of each class are much more numerous than persons generally suppose. Thus, the word "shot" generally conveys but one impression to the mind of the non-professional. It almost inevitably suggests the solid "round shot" of iron. But, in addition to round shot, there are solid steel shot, and solid chilled iron shot, hollow shot, case-shot, and grape-shot. The solid shot is the simplest and most primitive form of projectile, the object with which it is

employed being, of course, to kill or disable an enemy, or to batter down or penetrate his defences. When defences were of brick and stone, or wood, or when troops fought in the open, it sufficed to make the shot of cast iron; but when armour-plated defences came into vogue, it was necessary to use some other material. Accordingly, steel shot were introduced for use with the larger smooth-bore guns, with which some of our ships were still armed. The great cost of steel, however, and the success which had attended the employment of the famous Palliser "chilled" projectiles (of which more particular mention will be made hereafter), induced the authorities to give a trial to some solid spherical "chilled" iron projectiles, some of which still exist.* The chilled *spherical* projectiles were far from satisfactory. Their form was unsuitable to the brittle material, but it was thought that they were somewhat more effective than ordinary cast iron, and they were not much more expensive. The fact is, that no spherical shot are very effective against thick armour-plates—at least, any effect which may be accomplished can only be obtained at a disproportionate expenditure of power, and then only at very short ranges. No smooth-bore gun can compare with a rifled gun for penetration; because with the rifled projectile, if the weight of shot be equal to that of the sphere, the diameter will be less, and if the diameter be equal, the weight will be more; and we thus have either less work to do, and equal power to do it, or equal work to do, and more power to do it. To this must be added that the pointed form of head is far more favourable to penetration than is the hemispherical surface with which the spherical shot strikes the plate. Hollow shot were used by the navy against wooden ships at short ranges, in order to produce a greater splintering effect, and to carry more fragments into the vessel. They could not be used effectively at long ranges on account of their lightness. Of late years empty shells have been used as hollow shot when required; but at one time hollow shot constituted a separate projectile.

An application of small solid shot, weighing 1 lb. each,

* We reserve for the present such remarks as suggest themselves in connection with chilled projectiles, until we come to speak of the Palliser shot and shell.

must not be omitted. They are thrown sometimes from a mortar, in charges of one hundred shot. The shot are piled loose in the mortar over the powder, a piece of wood being placed between the powder and shot; and against crowds of men huddled together, or a fleet of small boats, these *pierrier** charges of pound-shot are very useful. Case-shot are used for firing at troops in masses at short ranges. They consist of cylindrical iron cases, filled with balls. The case is broken by the discharge, and its contents are driven forward in a conical shower to a distance of from 300 to 400 yards from the muzzle of the gun. When cavalry are charging home, or when troops present themselves within the range indicated, case-shot are terribly effective, and many a gallant charge has been checked, and many a gallant column thrown into disorder and panic, by a well-directed discharge of these destructive missiles.

Grape-shot are intended for use on much the same sort of occasions as would be selected for the use of case, except that, being made up with heavier balls, their range is somewhat greater. They were also useful for cutting and destroying the rigging of ships in naval actions. Originally, grape consisted of a canvas bag filled with balls, piled round an iron spindle through the centre of the bag, the bag being drawn together between the balls, or "quilted" by a strong line. In this form the grape somewhat resembled a bunch of grapes—whence its name. For several years the quilted grape has been superseded by grape of a pattern known as the "Caffin." This pattern consists of four horizontal iron plates, connected by a spindle through the centre, and having three tiers of shot arranged between the plates. The advantages of this pattern are, that it is less perishable than the old-fashioned grape, the bag and cord of which are liable to rot and fall to pieces; that it is more portable, as it can be carried in pieces, and put together when required; and that the parts are interchangeable. During the past three or four years the manufacture of grape has ceased, it being considered that case-shot will answer all the purpose.

* From the French word *pierre*, a stone—from a number of stones having been in early days fired in this way instead of shot.

This completes the list of shot for smooth-bore guns. We will give in our next chapter descriptions of the various shells and other projectiles used with this class of ordnance.

CHAPTER VIII.

GREAT GUNS AND THEIR PROJECTILES (*continued*).

In our last chapter we treated of smooth-bore ordnance, and of the various kinds of shot which are used with the same—solid, steel, chilled, hollow, case, and grape shot.

We pass now to the consideration of the second group of projectiles, Shells. There are two great classes of shell—common shell and Shrapnel shell. The common shell, for smooth-bore guns, is a hollow sphere of cast iron filled with powder and fitted with a fuze, which is so arranged as to explode the shell either at a particular time after it has left the gun, or when it strikes against some hard object. A shell is, in fact, a small mine, which is transferred by the power of a gun to any spot where its effect may be required to be produced: it has been called a "flying mine," and the effect, it will be observed, is really independent of the gun. That is to say, a common shell, if deposited on a particular spot by hand and then fired, would cause almost as much destruction as if it had been shot on to that spot from a gun. This, at least, is the primary application of a common shell, and it is one which it is important to appreciate, because it constitutes the leading distinction between shells of the common and shells of the Shrapnel class. It follows from the above that a common shell acting as a mine is especially destructive against the *matériel* of an enemy. It destroys his parapets; it blows down his walls and defences; it carries destruction into his towns and villages; but, beyond and above all, it is especially terrible when it can be introduced into his ships. Shells are more dreaded by the sailor than any other projectile, and naturally so; for the bursting of a shell in the confined space between the decks of a vessel is destructive alike to men and

material; it blows the former to pieces, it destroys and sets fire to the latter, and it causes confusion and terror by its noise and smoke. The following passage, which gives a "realised epitome" of shell effects on board ship has been often quoted, but may be here fitly reproduced. It is an account of the fight between the iron-clad *Merrimac* and the wooden ship *Congress*:—"The first shell that burst within the *Congress* killed every man at the nearest gun; another and another burst among the crew, and the ship was soon a slaughter-house. Operations were now out of question. The wounded were in crowds horribly cut up. The ship, too, was on fire; the shells had kindled her woodwork in various places. Nearly all the guns were dismounted, the bulkheads blown to pieces, handspikes and rammers shivered, and the powder-boys all killed. Everything was in fragments, black or red, burnt or bloody. This horrible scene lasted about an hour and a half, and then she struck." This vivid description was given by an eye-witness.

A secondary use of the common shell is to act much as the Shrapnel acts—viz., to burst somewhat in advance of the object fired at, when the fragments, continuing their flight, spread out and act in the same way as a charge of case or grape. But this is to be understood as distinctly a secondary use of common shells; for in this case the large bursting charge which the shell contains is in a great measure thrown away. Indeed, it may be said to detract from the efficiency of the projectile, because it blows a number of the fragments sideways, and arrests the progress of others.

But this brings us to that class of shell which is specially intended to act in this way—Shrapnel shell. The first idea of these important projectiles was conceived by General Shrapnel, of the Royal Artillery, at the siege of Gibraltar, in 1781. The guns were firing at a range beyond that of case or grape, and some effective *direct* fire was made with common shell fired from 24-pounders with large charges of powder. The projectile's velocity was very great, and the loss to the enemy was considerable. It then occurred to General Shrapnel that if he were to fill these shells with musket and carbine balls, reducing the bursting charge to a

minimum, consistent with the opening of the shell, and increasing the firing charge to a *maximum*, he would be able to produce a still more destructive fire. In this change we note the distinctive difference, which cannot be too clearly appreciated, between common and Shrapnel shell—viz., the difference, that while the former depends upon the explosive effect of its own charge, the latter depends upon or derives its effect from the charge of the gun. A high velocity is not necessary in the first case; it is essential in the second. A large bursting charge is essential in the first case; it is not only not essential, but absolutely prejudicial in the second. The original Shrapnel shell, as designed by General Shrapnel, was, in fact, a thin common shell filled with bullets instead of powder, and having only so much powder in among the balls as would suffice to open the shell. The object of making the shell as thin as possible was, first, that it might contain as many balls as possible; secondly, that a very small bursting charge might open it. These projectiles were first introduced about the year 1803, and were used at the battle of Vimiera in 1808, and at other actions during the Peninsular war, with an effect to which the French, against whom they were fired, bear ample though unwilling testimony.

The action of the shell is as follows:—It leaves the gun like any other spherical projectile, travelling to the point at which the time-fuze has been set to explode it—which should be a short distance in front of the object aimed at. When it arrives at this point, if the action of the fuze be satisfactory, the shell will be opened, and the bullets and fragments will "continue their forward course with a communicated velocity equal to that of the shell at the moment of fracture, and describing, as they slightly disperse, 'a curved cone, the apex of which is at the point of explosion.'" The Shrapnel shell thus acts as case or grape at distances beyond those at which case and grape can be effectively employed. The Shrapnel shell has practically the effect of carrying forward the muzzle of the gun to within such a distance of the enemy as will enable a case-fire to be delivered. Actually, the muzzle of the gun is, of course, not advanced; but practically this is what happens, for the

breaking-up of the projectile, which with case occurs at the muzzle, is postponed until the projectile arrives within a short distance of the enemy. Indeed, when Shrapnel

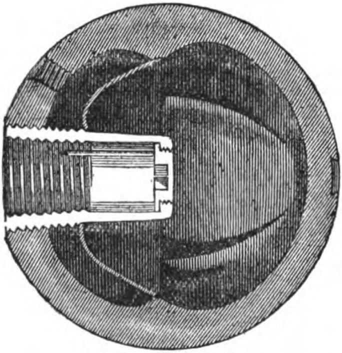


Fig. 14.—SECTION OF DIAPHRAGM SHRAPNEL SHELL, WITHOUT BULLETS.

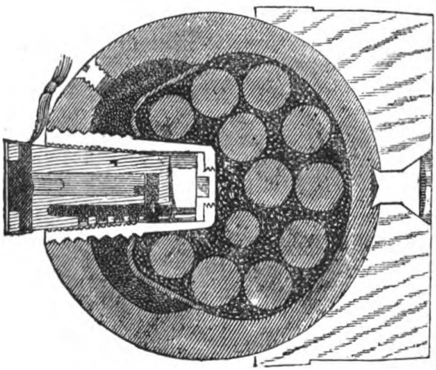


Fig. 13.—SECTION OF DIAPHRAGM SHRAPNEL SHELL, WITH BOXER TIME-FUZE COMPLETE.

shell were first introduced, they were called by a name which exactly describes them—"spherical case shot." The present name was not adopted until many years afterwards, as a compliment to the inventor. Since the

first introduction of Shrapnel shell, some important improvements and modifications have been adopted. It was found that the shells sometimes were broken up by the shock of discharge, due to the friction of the powder between the balls. To obviate this it was necessary to separate the powder from the balls, and this was done by introducing into the existing store of Shrapnel a tin cylinder, which occupied the centre of the shell, and contained the bursting charge. These shells were known as "improved Shrapnel," and they have only recently disappeared from the service. When new shells had to be made, General (then Captain) Boxer, R.A., suggested a different arrangement. He proposed to separate the bursting charge from the bullets by enclosing it in a small chamber formed on one side of the shell, by the insertion of a wrought-iron plate or "diaphragm." The accompanying drawings (Figs. 13 and 14) show the construction of the "diaphragm Shrapnel shell."

The advantage of placing the bursting charge at one side, instead of in the centre, was that it avoided the excessive dispersion of the balls at the moment of rupture. But in order to ensure the proper opening of the shell, it was necessary to provide it with internal grooves, or "lines of least resistance," down which the powder would act. The powder is introduced into the chamber through a small loading-hole, and the fuze communicates with the powder in this chamber through a small fire-hole in the brass socket. To prevent the bullets from conglomerating under the shock of discharge, they are made of hardened lead, and have coal-dust shaken in between them. Such is the diaphragm Shrapnel shell for smooth-bore guns. We shall see hereafter how General Boxer has successfully applied the principles of this construction to the Shrapnel shell for rifled ordnance.

It will be observed that the shell in our drawing is fitted with a wood bottom, riveted on. All shells are fitted with one of these bottoms, or "sabôts." They serve the double purpose of presenting the right side of the shell—*i.e.*, the side away from the fuze—to the charge, and slightly diminishing "windage" (the space between the shell and bore), and thus reducing the escape of gas and the tendency of the projectiles to *ricochet* along the

bore. With bronze guns it was necessary to provide the shot, as well as the shell, with these bottoms, because otherwise a bounding movement of the shot became established, to the speedy destruction of the gun, and to the almost immediate destruction of all accuracy of fire. The method of attachment adopted for these bottoms—an expanding copper rivet—is simple and ingenious, and a great improvement on the plan formerly adopted, namely, "strapping" on the bottom with tin "straps."

We have now treated of shot and shell. There remains a third class of projectiles to speak of—*Incendiary projectiles*. Of these there are six—viz., red-hot shot, Martin's shell, carcasses, ground light balls, parachute light balls, and smoke balls.

Red-hot shot are merely ordinary cast-iron shot heated to a "wafer" red heat, and fired, with reduced charges, against wooden shipping or any combustible material. It is necessary to fire them with reduced charges, because the expansion of the shot, by reducing the windage, increases the strain upon the gun, and because red-hot shot are required to lodge in the object fired at, and not to pass through it. These projectiles were used with great effect, and on a large scale, at the siege of Gibraltar.

Martin's shells have, in a great measure, replaced red-hot shot; although both descriptions of projectiles have lost their original value, in consequence of the substitution of armour-plated for wooden vessels. Martin's shell, so called after its inventor, a civilian, consists of a thin spherical cast-iron shell, with an interior lining of loam; shortly before use the shell is filled with molten iron. In order to ensure the breaking up of the shell on striking an object, the sides are made thinner than the top and bottom. The loam-lining, being a good non-conductor, serves the double purpose of keeping the iron in the interior hot and the external shell cool for a longer time than would be possible if there were no such lining. The shell is intended to be fired against an inflammable object—such as a wooden ship. The shock of concussion breaks the shell, and the molten contents are scattered about, setting fire to everything combustible upon which they may fall. These shells were considered by the committee which introduced them to possess greater in-

cendiary power than red-hot shot. On the other hand, there is a certain amount of trouble and inconvenience involved in the preparation of the liquid iron. But when these difficulties are surmounted, and when the shells are used under favourable circumstances, they have been proved to be very formidable instruments of destruction.

Carcasses are thick iron shells, filled with a combustible composition, and having three holes for this composition to burn out of. The composition consists of a mixture of saltpetre, sulphur, rosin, sulphide of antimony, turpentine, and tallow. It burns with great violence for from three to twelve minutes, according to the size of the carcass, which varies from the 12-pounder to the 13-inch. Carcasses are thrown into an enemy's works, to set fire to his houses, stores, etc. etc. The composition becomes ignited at each vent by the flash of the discharge, and continues burning after the carcass has fallen until it is expended. So violently does the composition burn, that it is almost impossible to extinguish it. It will even burn under water. The best mode of dealing with a carcass is to endeavour to roll it away from all inflammable material, and to smother it with earth.

The ground light ball (Figs. 15, 16, 17), is another projectile of this class. It is, however, useful rather for illuminating than for incendiary purposes. It consists of an oblong skeleton iron frame, covered with stout canvas and filled with an inflammable composition, consisting of saltpetre, sulphur, rosin, and linseed oil. The projectile has four or five vents, according to its size, from which the composition burns, for from nine to sixteen minutes, according to the size. These ground light balls are thrown from mortars at night into an enemy's work, to discover his working parties; and they are also serviceable, in the absence of carcasses, as incendiary projectiles. They are, however, open to some serious objections. In the first place, an oblong projectile is not suitable for firing out of a smooth-bore gun; neither range nor accuracy can be obtained with it. Again, if they fall short of the object, their smoke makes a sort of screen. If they fall into a ditch or on to muddy ground they are smothered; and even if they do fall in the right place, they can be very

easily covered over with earth, and so rendered useless as lights. Even when not extinguished, the composition is of so dull a nature that its illuminating power is very small, while the area illuminated by a projectile on the ground is

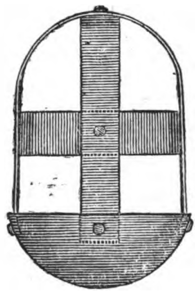


Fig. 15.—SKELETON FRAME OF GROUND LIGHT BALL.

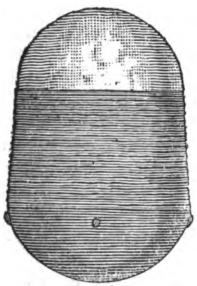


Fig. 16.—GROUND LIGHT BALL COMPLETE.

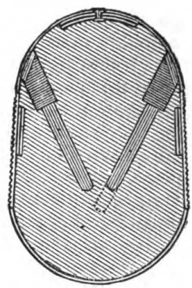


Fig. 17.—SECTION OF GROUND LIGHT BALL.

necessarily restricted, even under the most favourable circumstances.

A good many of the foregoing objections, if not all, were met by General Boxer in his ingenious Parachute Light Ball. It consists of a thin wrought-iron shell, containing

two half-shells of wrought iron (Fig. 18), the lower of which contains a brilliantly-burning composition of saltpetre, sulphur, and red orpiment, and the upper a calico parachute, the lower part of which is attached by chains to the composition hemisphere. The shell, fitted with a fuze, is fired from a mortar. The fuze is timed to explode a small bursting charge when the shell attains its maximum

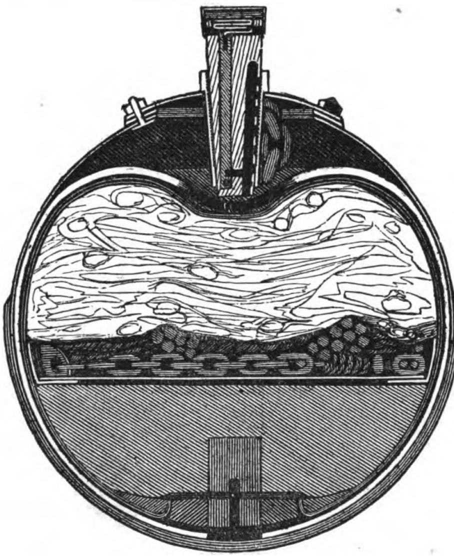


Fig. 18.—SECTION OF PARACHUTE LIGHT BALL, WITH FUZE.

elevation over the area or object required to be illuminated. On the explosion of the bursting charge, the outer shell is opened, and the two inner hemispheres begin falling. The lower hemisphere, which contains the composition, being the heavier, falls more rapidly than the other, which has, indeed, received a momentary impulse by the action of the bursting charge in the opposite

direction. This jerk, and the more rapid falling of the composition hemisphere, cause the calico parachute to be pulled out and expanded (Fig. 19), and it then floats the composition hemisphere slowly down over the object to be illuminated, the composition burning brightly out of a hole at the bottom of the hemisphere, for from one to three minutes, according to size. In addition to over-

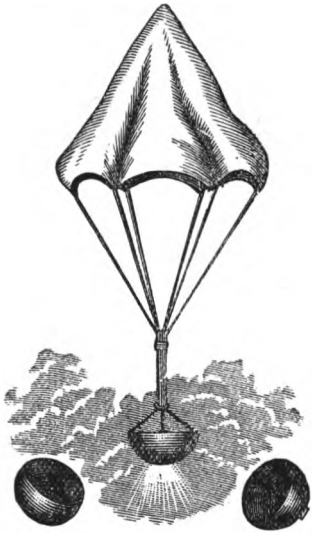


Fig. 19.--PARACHUTE LIGHT BALL IN ACTION.

coming all the difficulties and objections enumerated above as belonging to the ground light ball, the parachute light ball possesses the advantages of being serviceable at sea, or to illuminate an enemy's fleet, which the ground light ball necessarily cannot be. It can also be fired from a very light and handy mortar. This construction of projectile has been very effectively employed for firework purposes.

The Smoke Ball hardly needs any mention. It is merely a paper shell filled with a composition of gunpowder, saltpetre, coal, pitch, and tallow, which when ignited emits a dense and suffocating smoke, which is stated to be useful in expelling an enemy from mines, and in concealing one's own operations. These projectiles have also served a peaceful use in the Arctic regions, where they were employed for signalling purposes — the long column of black smoke standing out prominently against the white background of these snow-clad regions.

This completes the list of projectiles for smooth-bore guns, if we except the Manby shot, for saving lives from shipwreck, and which is not to be considered a weapon of war. We will now pass forward to another section of our subject.

CHAPTER IX.

RIFLED GUNS.

THE increasing and ever-active tendency to multiply the destructive effects of fire-arms, by increasing their range and precision, and by supplying them with projectiles more and more deadly and irresistible, naturally operated to recommend the conversion of the smooth-bore gun into the rifled gun, just as it had caused the supersession of Brown Bess by the Enfield rifle. Indeed, it may be said that the introduction of rifled small arms rendered it not a matter of choice but a matter of necessity for the artilleryman to develop the weapons of his craft in the same way, and, as far as possible, in the same degree. If artillery was to hold its place at all, it must meet the Enfield and the Minié rifles with a field-piece as superior to those weapons as the old smooth-bore 9-pounder was superior to Brown Bess; and the device by which the infantry soldier's weapon had been rendered so much more powerful was naturally resorted to by the artillerist, to increase proportionally the power of his own particular arm. We had got the rifled musket; it was therefore necessary for

us to have the rifled gun. We trust we shall not be misunderstood as wishing to affirm that the rifled gun was first proposed after the introduction of the Enfield rifle, and in consequence of it. Such a statement would be promptly and properly contradicted by antiquarians, who would point to occasional examples of very ancient rifled guns; and by experimentalists, who would remind us of Mr. Joseph Manton's rifled 6-pounder of 1790, of Lieutenant-Colonel Dundas's rifled gun of 1836, of the Cavalli gun of 1846, of the Wahrendorf gun of 1847, of Captain Norton's experiments with rifled cannon, and many others. But the introduction of rifled small arms certainly gave an impetus and earnestness to the exertions to introduce a rifled cannon which had before been wanting, and experiments which had up to that time possessed only a sort of speculative and uncertain interest now became invested with a new power, which drew towards them the attention of the military world.

Before proceeding to enumerate some of the more remarkable devices for communicating a rifled motion to the projectiles of cannon, it may be well to say a few words as to the object of rifling a gun. What is rifling intended to accomplish? What do we gain by it? To this the first answer will perhaps be, We gain the power of firing an elongated instead of a spherical projectile. But this answer would be in part incorrect. It is true, but it is not the whole truth; for we may remind our readers that the first rifled small arm in use in the British service was, as stated in a former paper, the Brunswick rifle; and the Brunswick threw not an elongated but a spherical belted ball. The first object of rifling a gun or small arm, then, is to obtain rotation on a fixed axis. This object is equally aimed at whether the projectile to be fired be spherical or elongated. In the case of the spherical ball, the rotation upon a fixed axis gives increased accuracy, by eliminating in a great measure the errors due to the eccentricity and irregularity of the projectile. Projectiles cannot in practice be made absolutely and uniformly true as to concentricity, weight, and form, and any departure from absolute truth in these points is attended in a ball fired from a smooth-bore piece with a corresponding loss of accuracy. But if a fixed rotatory

movement be communicated to that ball, the uncertain rotation due to the position of the centre of gravity will disappear, and with it one source of error; while the inaccuracy due to any irregularities of form and surface will be greatly diminished in consequence of the pressure of the air being more equally distributed around the projectile, the position of which in reference to this air is constantly changing. So that when a spherical ball is fired from a rifled piece, we get at once greater accuracy, and this is an advantage which belongs to rifling, whether elongated projectiles be employed or not. But rifling is more valuable as rendering possible the use of elongated projectiles, with all the advantages which flow from their employment. Why cannot elongated projectiles be fired from smooth-bore guns? Because of the pressure of the air acting upon them unequally, and causing them to turn over in flight. "If the centre of gravity of the projectiles be very far forward, it is possible," says Lieutenant-Colonel Owen, in his admirable "Modern Artillery," "to fire them from smooth-bore guns at short ranges." But this is the only case in which an elongated projectile could be fired without rotation; unless, indeed, we could suppose a shot fired in a vacuum, in which case, as there would be no air to press upon it, it would not turn over. If rapid rotation be established upon the longer axis of the projectile, the velocity of rotation will more than counterbalance the pressure of the air, and will prevent the projectile from being turned over. Any one who has amused himself with the gyroscope, or even a child who has played with a top, will know that the spinning motion gives a stability to the axis of rotation which, as long as the spin is strong enough, sets other disturbing forces at defiance. Thus a top or a gyroscope will spin at an angle with the horizon which it could not possibly maintain if it were not in motion. Indeed, a top could not stand at all without being spun, and the wobbling movement which precedes its fall indicates the point at which the force of gravity is beginning to reassert its sway, and to overcome the failing rotation. These are elementary truths, but they perhaps explain better than more recondite examples the effect of rifling upon a projectile.

Well, then, having advanced thus far—having esta-

blished that rifling neutralises some of the causes of inaccuracy in the projectile, whether spherical or elongated, and that without it it would not really be practicable to fire an elongated projectile at all—we have to inquire further, what are the advantages of firing elongated projectiles? Those advantages are as follow:—In the first place, weight for weight, the elongated projectile presents a diminished surface for the resisting medium—whether air, or iron, or wood, or water—to act upon. Weight for weight, therefore, the elongated projectile will range and penetrate farther than the spherical projectile of the same material. Or, weight for weight, equal results may be obtained with the elongated projectile with a reduced charge of powder. If the surface of the elongated projectile be increased to that of the sphere with which it is compared, its weight will be greater, and thus it will have greater powers of overcoming an equal resistance. Fourthly, it is often a great advantage to make the striking part of a projectile of a peculiar form and of a peculiar material. The shape of the head will greatly affect the flight; the shape and material of the head will greatly affect the penetrative power. The Palliser projectile of chilled iron would not be possible with an obtuse or hemispherical form of head. It is necessary, as will hereafter be more fully explained, to have a head of a form suitable for neutralising the brittleness of the material, and this is possible with an elongated shot which goes point foremost—it would not be possible with a sphere. Again, the heads of the present Palliser shot are made harder than the bodies, as the gouge or chisel is made harder than its handle. This would not be possible with the sphere. Every projectile in the service has a head of a form which is considered suitable for flight—for cleaving its way with the minimum of resistance and disturbing effect through the air, just as ships are made with bows suitable for easy passage through water. Such an arrangement would not be possible with a sphere. Fifthly, as an elongated projectile meets, in relation to its weight, with less resistance from the air than a spherical projectile, the trajectory of the former will, *cæteris paribus*, be flatter. Sixthly, all elongated projectiles for the same gun can be made of the same *weight*, if desired, so as to be fired with

the same charge of powder, and the same elevation. With the sphere, all the projectiles for the same gun must be made of the same *size;* and thus the common shell which is filled with powder, will weigh considerably less than the Shrapnel, which is filled with leaden bullets, and will require a different elevation. Seventhly, if a specially long or powerful projectile be required—as, for example, a "double shell"—this requirement can be satisfied with elongated projectiles, it cannot be satisfied with spheres. Eighthly, the fact of a projectile travelling head foremost greatly facilitates the preparation of a suitable percussion fuze, as it is only necessary to provide for action in one direction. This advantage would, it is true, be possessed by the *rifled* sphere, and is therefore rather an advantage of rifling abstractedly than of that particular application of rifling which gives us the elongated projectile. The same may be said of the advantage which rifling gives in respect of shells which are required to act or open to the front in any particular way. Thus, the Palliser shell is required to strike point foremost; the Boxer rifled Shrapnel is required to deliver its bullets to the front.

The advantages of rifling may therefore be summed up, as pointed out by Captain Orde Browne, R.A., in his "Treatise on Ammunition for Rifled Ordnance," as follow:—

1st. Accuracy.

2nd. Simpler action of percussion or concussion fuzes.

3rd. Distribution of the metal with a view to the special requirements of each projectile.

The above advantages apply whether the rifled projectiles be spherical or elongated.

Then, from the use of elongated projectiles, which rifling renders possible, we get,

4th. Power of making the head of any form required.

5th. Greater range or penetration.

6th. Saving of powder.

7th. Flatter trajectory.

8th. All projectiles for the same gun may be brought to the same weight.

9th. If required, a specially heavy projectile may be given to any gun, for exceptional use.

These are the advantages which we realise from rifling

our guns. Let us now pass on to observe in what way this rifling has been proposed to be accomplished.

To most persons the idea of rifling almost necessarily suggests a gun with grooves cut in it, and shot furnished with studs or other projections to fit those grooves. But although this may be the simplest and most natural way of rifling a gun, it is very far from being the only way. The Whitworth gun, for example, has no grooves, properly so called, and no projections upon the shot. It is, roughly speaking, a spirally hexagonal bore, which fires a spirally hexagonal shot. The Lancaster gun had an oval bore, and fired an oval shot. Then there have been numerous propositions for reversing the ordinary method of rifling, and making the grooves in the shot, with corresponding projections in the gun. But it is not necessary that the gun should be rifled at all. The Mackay gun is a smooth-bore, which fires a grooved projectile, the rush of gas along these grooves being supposed to communicate a rotatory motion to the projectile. Many proposals have been made for communicating rotation by the pressure of the air upon the projectile after it has left the bore, by acting upon oblique planes or channels, either in front or in rear of the shot. The Museum of Artillery at Woolwich contains many specimens of each of these different modes of rifling. Looking at them broadly, we shall find that they may be classified, as pointed out by Lieutenant-Colonel Owen, under three heads :—

1. Mechanical means inside the bore of the gun.
2. The action of the powder-gas upon the shot inside the bore.
3. The action of the air upon the projectile after it has left the bore.

The common object which all proposers of systems of rifling have had in view, is the spinning of the projectile on its longer axis, and with that axis as nearly as possible coincident with the axis of the bore or its prolongation. It is important to do this in a manner the least injurious to the guns, which will permit of easy loading, and which will impose no serious mechanical difficulties upon the manufacturers of the guns and projectiles. To discuss the merits and demerits of the various systems of rifling would occupy more space than can now be afforded, and

would be beyond the scope of this little work. Indeed, allusion has been made to the various experimental modes of communicating a rotatory motion to projectiles chiefly to warn those who may contemplate the trial of some supposed novelty in rifling that they will do well first to inspect the valuable collection of rifled projectiles which exists at Woolwich, and to learn from them the proportion of failures to successes.

The system of rifling of which it is first necessary to make mention at this stage of the subject is that employed by Sir William Armstrong in his original guns. The Armstrong shot was coated with a leaden coating, slightly larger than the bore, and which on the explosion of the charge became forced into the numerous shallow spiral grooves with which the guns were provided, and which thus spun the projectile. The advantages of this system, the *système forcé* (as the French call it), are that it gets rid of windage, that it insures complete centreing of the projectile, and that it gives greater accuracy. *Per contra*, the system is one which entails the use of lubricators, it imposes a great strain upon the gun, it is very costly, on account of the price of the lead coating, and the lead-covered projectiles are very liable to get disfigured in transport. Moreover, when lead-coated projectiles are fired against armour-plated ships, the lead coating, although it has increased the momentum of the shot, acts as a bar to its free progress through the plate, and thus lessens its power of penetration. The difficulties which were at first experienced in connection with the firm attachment of the lead coating have been overcome by the adoption of the plan proposed by Mr. Bashley-Britten, of soldering on the lead with zinc solder, instead of attaching it mechanically. All the breech-loading guns in the English service fire lead-coated Armstrong projectiles.

The muzzle-loading guns fire studded shot, and are rifled with three or more grooves, according to their size. An ingenious system of grooving, known as the "shunt" system, which was designed by Sir William Armstrong, is fast dying out, and hardly calls for notice. It is merely necessary to observe that with this system the shot loaded easily on the deep side of the groove, and in coming out

hugged the opposite or "driving" side, being "shunted" in its passage up the bore on to a shallower level. The objection to this system was that it was apt to strip the studs off the projectile, by throwing on to them a sudden strain at the moment when the shot took the shallower level. In some instances it is considered the strain acted injuriously upon the gun.

The "Woolwich" guns—by which is meant all our heavier muzzle-loading rifled guns—have a groove very nearly akin to that used in the French guns. In some cases the spiral is made uniform throughout the bore; in the majority of cases it is quicker at the muzzle than at the breech. The supposed advantage of the increasing twist is that it slightly diminishes the strain upon the gun. The projectile meets with little or no resistance from the grooves at the instant when it is propelled forward by the ignition of the charge, and it is only as the projectile travels forward in the bore that the resistance due to rifling becomes sensible. But this resistance is far less than is commonly supposed, and it is doubtful if the increasing spiral really affords anything like that amount of relief to the guns which was at one time believed. It is considered by some that the increasing spiral gives also greater accuracy of fire.

In the field guns the form of groove is rather different from that of the Woolwich guns, and the play between the studs and grooves is less. But these are details with which it is not necessary to encumber the present volume. It will be sufficient to observe that there are two main systems of rifling in vogue in the British service—namely, the system of many shallow grooves, with lead-coated projectiles, for the breech-loading guns; and the system of few deep grooves, with studded projectiles, for the muzzle-loading guns. The *rationale* of rifling has also been explained, and the advantages which it gives us have been set forth. We will in our next chapter pass on to the construction of our rifled guns, and show the principles upon which they are built.

CHAPTER X.

RIFLED GUNS (*continued*).

THE superiority of rifled guns in point of range and accuracy has been recognised by artillerists for more than two centuries back, and various have been the attempts during that period to construct pieces able to shoot elongated projectiles rotating on their longer axis ; but these attempts one and all failed, in consequence, in no small degree, of the backward state of mechanical and metallurgical science. It was not, however, till the general introduction of rifled small arms during the Crimean War that rifled guns became actually necessary, in order that artillery might remain, as before, the principal arm on the field of battle.

" Such being the state of the case, it was indeed fortunate for the ascendancy of artillery that, owing doubtless to the spread of railways, suspension bridges, etc. etc., the requisite improvement in metallurgy and in mechanical appliances should have opportunely taken place in recent years. It is only lately that the manufacture of cast steel as a material for rifled ordnance has made rapid progress, whilst the difficulties which used to attend the forging of wrought iron in large masses were so great that a heavy anchor was one of the greatest achievements of the forge-master until the comparatively recent introduction of steam-hammers enabled him to forge our modern monster guns ; and, thanks to the able mechanicians of the day, we have now rifling machines so perfect and easily manipulated that the operator could, if he pleased, engrave his name in the bore of a gun, and, withal, so accurate is their action that they work true to less than $\frac{1}{1000}$th of an inch, a dimension which can now be very easily measured by means of a Whitworth's micrometer, but which is fifty times too minute to be ascertained by the primitive measuring instruments of the last generation of mechanics."*

* This and the succeeding paragraphs in this chapter between inverted commas are extracted from papers on the subject published in the *Royal Artillery Institution Proceedings*, by Captain Stoney, R.A., late Assistant-Superintendent Royal Gun Factories.

Our limited space prevents us going further into the reasons why a rifled gun should be stronger, both in material and construction, than a smooth-bore, beyond stating that the rifled gun is required to give a spiral motion to an elongated projectile about 2½ times heavier than the *ball* which is simply projected from the smooth-bore gun of the same calibre (diameter of bore); so that there is a good deal more strain on the former description of gun than on the latter. We must say, however, that this increased strain could not, as a general rule, be met by merely increasing the weight of the piece, for it is a well-known fact that the strength of a cylinder is not in proportion to its thickness, and that in the case of a ponderous gun of a too weak material, the interior would be ruptured before the exterior portions could come into play.

Mr. (now Sir W.) Armstrong was the first in this country who brought a system of rifled ordnance to practical perfection. The principles of his gun-construction consist essentially—

"First, in arranging the fibre of the iron in the several parts so as best to resist the strain to which they are respectively exposed; thus the walls or sides of the gun are composed of coils with the fibre running round the gun, so as to enable the gun to bear the transverse strain of the discharge without bursting, whilst the breech end is fortified against the longitudinal strain, or tendency to blow the breech out, by a solid forged breech-piece with the fibre running along the gun. Secondly, in shrinking on the successive parts together with tensions so regulated that each part shall do its due proportion of work on the discharge of the piece; thus, the outer coils contribute their fair share to the strength of the gun, whereas in an ordinary homogeneous gun the inner portions receive the brunt of the explosion, whilst the exterior ones are hardly affected by it at all.

"By a combination of these two principles (which are applicable alike to breech-loaders and muzzle-loaders) a gun is obtained which may be calculated to be twice as strong as a gun of the same weight and shape made out of a solid forging."

The first gun Sir William Armstrong brought to the notice of the War Office was a breech-loading 3-pounder,

with poly-grooved rifling and lead-coated projectiles—in fact, a type of what is commonly called the Armstrong gun. It was tried in 1855, at the School of Gunnery, Shoeburyness, in Essex, and made remarkably good practice at long ranges. Heavier guns of the same description were subsequently tried; and having proved their claims to accuracy, strength, and range-power, the excellence of the system was acknowledged, and the whole series of Armstrong breech-loaders, from the 6-pounder, of 3 cwt., to the 7-inch* (100-pounder) of 82 cwt., including the 9-pounder and 12-pounder field-guns, the 20-pounder guns of position, and the 40-pounder siege-guns, was issued for land service, and similar guns were also distributed through the different classes of vessels in the navy.

All these breech-loaders are made altogether of wrought iron, each gun consisting of a coiled inner barrel, a forged trunnion-ring, and one or more coils, according to its size; for example, the 6-pounder has only one coil, whilst the 7-inch has six.

The gun is loaded through a hollow screw, called the "breech-screw;" the "vent-piece" (so called because the vent goes through it) is then dropped into the "slot," and the breech-screw being screwed up by means of the "lever," the breech is closed, and escape of gas completely prevented by means of copper rings on the face of the vent-piece and end of the barrel. The annexed illustration (Fig. 20) of a portion of the 6-pounder will explain the breech arrangement better than a page of description. The rifling is "poly-groove" (we are not responsible for the etymology of this word); and the "grooves" and "lands" are nearly of the same dimensions in all the natures, the only difference being in the number; thus the 6-pounder has 32 grooves (see Fig. 21), whilst the 7-inch has 76.

The Armstrong breech-loading guns were used in active service in China, New Zealand, and Japan, and answered remarkably well. Why, then, are muzzle-loaders more in favour? Because it has been proved by experiment that

* Below 7-inch calibre a rifled gun is designated by the weight of the shot and its own weight; 7-inch guns and upwards are designated by the calibre; and the weight is expressed in cwts., unless it is five tons or upwards, in which case it is expressed in tons.

they are equal to the breech-loaders in range, rapidity, and precision of fire, and much superior to them in the simplicity of their fittings and ammunition, as well as in

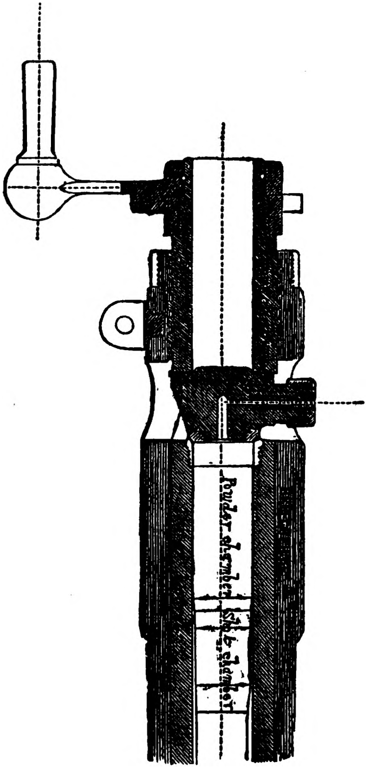


Fig. 20.

their non-liability to wear. There are, no doubt, advantages on the breech-loading side, and we think the Prussian field-gun, with the Krupp expanding wedge and

the Broadwell copper gas-check, on the whole, a simple and efficient breech-loader, but we do not think that any system of breech-loading has yet been found sufficiently safe, handy, and durable for heavy guns. In short, a breech-loading arrangement on a small scale, as in revolvers, infantry rifles, etc., is exceedingly convenient and satisfactory, but the difficulty of obtaining perfection of mechanism and ease of manipulation increases with the size of the weapon; and hence it is that when the introduction of armour-plated ships necessitated ordnance of great penetrative power, the British artillery authorities,

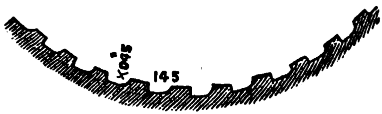


Fig. 21.

after long and exhaustive experiments, adopted muzzle-loaders; and this leads us to our muzzle-loading rifled guns.

The largest gun in the English service is the muzzle-loading rifled gun of 35 tons, or 700-pounder, and the smallest muzzle-loading rifled gun is the steel 7-pounder mountain gun, which was used in Abyssinia, and weighs only 150 pounds, that is, considerably less than a quarter of the weight of the projectile for the 35-ton gun. Indeed, it is absurd to see one of the big guns side by side with one of the little guns, and it is no wonder to learn that they are respectively spoken of as "Dignity" and "Impudence."

No other nation has got such powerful guns as we have. Herr Krupp, of Essen, the great German steel gun manufacturer, exhibited in Paris, in 1867, a breech-loader weighing 50 tons, and intended for a 1,000-pounder, but we believe it has never been fired. Russia and one or two other Continental powers have provided themselves with Krupp's steel breech-loaders, from 300-pounders downwards; while the remainder have followed our example, and adopted the heavy Armstrong muzzle-loaders for their ships and forts.

The 7-pounder mountain gun is made out of one block of cast steel, bored out and tempered in oil; that is, the

block of steel, after being roughly bored out for the barrel, is put into a furnace, where it is raised to a high heat, and then plunged into an adjacent bath of rape oil, in which it is allowed to cool and to soak for twenty-four hours. This process not only strengthens, hardens, and toughens the steel, but also increases its elasticity; and for a small gun the material so treated may be considered quite safe, and not likely to burst explosively. But a gun altogether of steel, even though thus improved, is of too snappish a nature to be trusted to bear the great and sudden shock of large discharges of powder, and so we deem it prudent to coil the steel round and round with wrought iron, after Sir William Armstrong's fashion; all our muzzle-loading guns,* therefore, from the new 9-pounder field gun, of 8 cwt., to the 700-pounder, of 35 tons, are lined with steel (which, from its statical strength and hardness, is the best material we know of for withstanding the strain and friction on a rifled barrel), and have on the exterior coiled wrought iron, which, from its pliant and fibrous character, is capable of checking and counteracting any explosive tendency on the part of the steel.

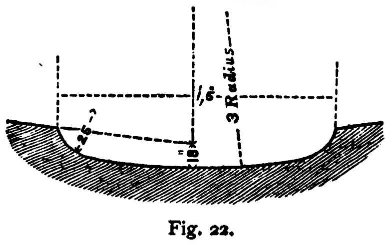


Fig. 22.

Up to 1867 all our heavy muzzle-loading guns were built up with many coils, like the breech-loaders, and fired (as they do still) projectiles having two studs for each groove, the number of grooves increasing with the size of the gun—the 7-inch having three grooves, the

* We have also a few 9-pounder field guns altogether of bronze for service n India, and some 64-pounders converted from 32-pounder cast-iron smooth-bores, but these may be said to be exceptional pieces.

9-inch six, and so on. Fig. 22 shows a full-sized section of the muzzle-loading groove.

"The 'Woolwich' guns built on this system, and lined with toughened steel, are sound and strong; but from the fine iron used, and the great number of exquisitely finished coils and a forged breech-piece, their manufacture was very costly; and as it was probable that several heavy guns would be required, the War Office pointed out the desirability of procuring some cheaper plan. Accordingly, the attention of the Royal Gun Factories was devoted to the question, and their efforts have been crowned with success. First, a cheaper iron, sufficiently strong for the exterior of the gun, was obtained; and, secondly, the plan which was proposed by Mr. Fraser, the principal executive officer of the department, was found to be less expensive than the original one.

"Mr. Fraser's plan is an important modification of Sir W. Armstrong's, from which it differs principally in building up a gun with a few long double or triple coils, instead of several short single ones and a forged breech-piece. There is less material, less labour, and less fine working, and consequently less expense required, for the 'Fraser' or present service construction."

For example, in addition to the steel barrel and cascable screw (breech-plug), a 9-inch gun of the Armstrong or original construction consists of a forged breech-piece, a B-tube, a trunnion-ring, and seven coils—ten distinct parts—shrunk on separately (Fig. 23); whereas a "Fraser" gun has only two, three, or four parts to be shrunk on, according to the size of the gun—the 7-inch and 8-inch having only two extra parts, the 9-inch three, and the 10-inch and higher natures four (Fig. 24).

From the fewer parts and the cheaper iron employed the Woolwich guns of the present construction only cost about £70 a ton, whereas those built on the original plan cost £100 a ton.*

Without entering into the theory of construction, it must be sufficient to state that specimen guns of this cheap construction were tested to destruction, and were proved beyond all doubt to be as sound and durable as

* A steel gun on Krupp's or Whitworth's plan costs about £170 a ton.

their original prototypes ; and we have no hesitation in asserting that England now possesses the simplest, safest,

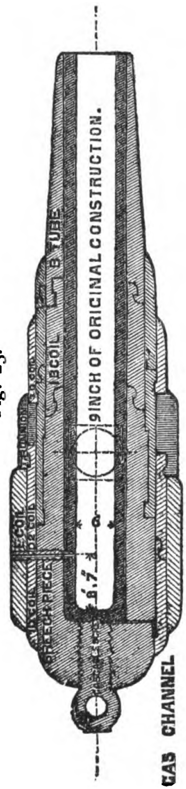


Fig. 23.

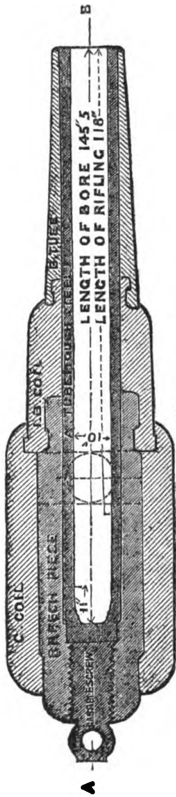


Fig. 24.

and cheapest system of efficient heavy ordnance in existence.

To give an idea of the way in which our heavy guns are

built up, we will take as the simplest example a 7-inch gun of 7 tons. The gun consists of only four separate parts—namely, the A-tube, or inner barrel of steel, the cascable, the B-tube, and the breech-coil.

The steel tube is bored out of a solid ingot to within a few inches of the end; it is then toughened in oil, like the 7-pounder mountain gun already described.

The cascable is a forged block of wrought iron, with a screw-thread cut on it.

The B-tube is formed of two coils joined together, each coil being made of one long bar of wrought iron, brought to a high heat, wound spirally round an iron mandrel, and then longitudinally welded under a steam-hammer.

The breech-coil is somewhat more complicated; it consists of a triple coil, a trunnion-ring, and a front double coil, all welded together. The triple coil is made by winding three red-hot bars of wrought iron successively over one another, and then, having raised the mass to a white heat, welding it like the single coil, for the purpose of closing its folds (Figs. 25 and 26).

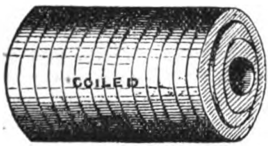


Fig. 25.

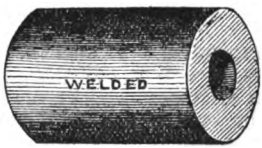


Fig. 26.

The front coil is made of two bars, in a similar manner. The trunnion-ring cannot be coiled, owing to the projection of the trunnions; it has, therefore, to be bored and formed out of a solid forging of wrought iron.

In order to join the three parts of the breech-coil into one solid mass, the trunnion-ring is expanded by heat, and dropped on a shoulder cut for it on the triple coil; the front coil is next dropped into the upper portion of the trunnion-ring, which is allowed to cool and contract, and thus bind the two coils together (Fig. 27). The mass is then heated and welded, and finally bored and turned to the proper size and shape (Fig. 28).

The parts of the gun being all ready, they are put together in this way: the steel tube (having been finely turned) is placed upright in a pit, and the B-tube, which is just too small to go over it when cold, is heated and

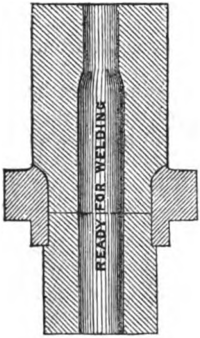


Fig. 27.

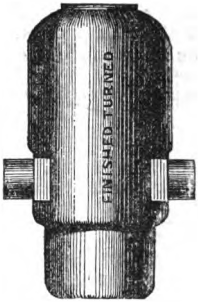


Fig. 28.

expanded, and is then dropped down on the chase end of the steel tube, which it grips in shrinking as it becomes cold (Fig. 29). The mass thus formed is inverted, and the breech-coil being heated, is shrunk on in a similar manner. Finally, the cascable is screwed carefully in, and thus the gun is completely built up (Fig. 30).

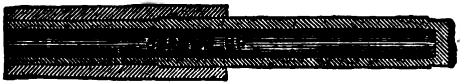


Fig. 29.

Some of our early rifled guns were manufactured by Sir William Armstrong and Co., at Elswick, Newcastle-on-Tyne, where some cast-iron smooth-bore guns are still "converted" for the Government, on Major Palliser's principle—that is, an old smooth-bore, a 32-pounder, for

example, is bored out and lined with a wrought-iron barrel, and converted into a rifled 64-pounder; but all our new guns, big and little, are now made in the Royal Gun Factories at Woolwich, where 6,000 tons weight of guns of all calibres can be manufactured in one year. It may,

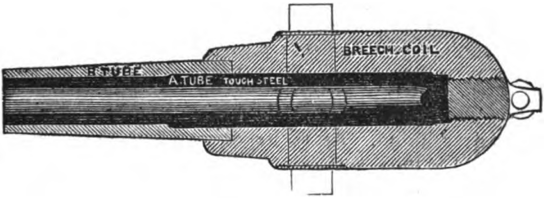


Fig. 30.

however, fix our ideas better to give the actual guns made or set in hand during last year (1871). They are as follows:—

12-inch guns,	of 35 tons	(700 pounders)	. . .	13
11 ,,	25 ,,	(530 ,,)	. . .	19
10 ,,	18 ,,	(400 ,,)	. . .	83
9 ,,	12 ,,	(250 ,,)	. . .	46
7 ,,	7 ,,	(115 ,,	. . .	28
7 ,,	6½ ,,	(115 ,,)	. . .	30
64 pounders,	of 64 cwt.		. . .	35
40 ,,	35 ,,		. . .	20
16 ,,	12 ,,		. . .	160

All the above are wrought-iron muzzle-loading rifled guns, lined with steel. There are in addition—

Bronze 7-pounder mountain rifled guns, of 3 cwt. .	15
32-pounders, of 58 cwt., converted to 64-pounders .	100

One projectile for the 35-ton gun (700-pounder) exceeds the weight of all those thrown from the whole broadside of a 74-gun ship in Lord Nelson's time. So much has the power of our guns increased since our last great naval battles!

CHAPTER XI.

RIFLED PROJECTILES.

In immediate connection with the two preceding chapters is the subject of rifled projectiles. The subject is not only a very important, but a very wide one—so wide, indeed, that we despair of doing justice to it within the limits which must necessarily be observed in a volume of this description. As to its importance, that must be evident to the most superficial observer. A gun, after all, is only the means of application of its projectile. It is the motive power of the machine, not the machine itself—it is the projectile which strikes and does the work. Therefore, upon the suitability of the projectile for the end for which it is designed depends ultimately the value of the gun. Even the "Woolwich Infant" firing snowballs, or discharging cast-iron shot against an armour-plated vessel, would accomplish nothing. And so the ultimate virtue—the effective value—of the gun resides in the projectiles, by which the destruction to life or material is wrought.

To attempt even to enumerate within a single chapter the varieties of rifled projectiles in the service would be vain. In the case of smooth-bore projectiles, where the sphere is the only practicable form,* and where there are no changes to be wrung on modes of rifling, the classification is comparatively easy. But with rifled projectiles, we have not only the shot or the shell, each with its varieties, but we have of each the breech-loading and the muzzle-loading type, as well as infinite varieties of form and proportion.

Breech-loading projectiles, although they exist in great numbers in our service, are gradually disappearing before the more simple, less expensive, but not less efficient, muzzle-loading projectiles. As has been already explained in preceding chapters, the breech-loading projectiles in

* Except in the case of such exceptional projectiles as the smoke ball and Manby's shot.

use in the English service are of a construction suggested by Sir William Armstrong—viz., an iron projectile, coated with a leaden coating slightly larger than the bore, which on the explosion of the charge becomes forced into the shallow grooves of the rifling, thus communicating the required rotary motion to the shot. It should be clearly understood that the lead coating is merely a means of spinning the projectile. It is not an essential or integral part of the projectile—that is to say, not merely may breech-loading projectiles be spun by other means than a lead coating, but this lead coating may, and does in fact, cover an infinite variety of construction of projectile. Some of the salient advantages and disadvantages of this system have already been mentioned in a former chapter. To discuss this branch of the question as it merits is impossible here. Suffice it to say that a series of experiments, carried out almost without intermission, and by all sorts of committees, since 1858, has ultimately resulted in the decided preference of studded to lead-coated projectiles for our service. Gradually projectiles of the latter type will disappear; and although other nations, such as the Germans, appear to cling to them, it is not improbable that fuller experimental inquiry will tend to the same conclusions as those at which we have arrived. The normal type of rifled projectile in our service is now a muzzle-loader, the spin being given to the projectile by means of studs, set on so as to suit either a uniform or an "increasing" spiral, according to the rifling of the gun. The material of the studs, their size and strength, are proportioned to the strain which they will have to bear. They are either made of copper or of gun metal (copper and tin), and are attached to the projectiles by means of "undercutting."

Passing from the means of spinning the projectile, to the projectile itself, we find several varieties, according to the nature of the work required to be accomplished. The simplest form of rifled projectile is the shot. Of this there are two or three principal types—the ordinary solid shot, the case-shot, and the Palliser shot. The ordinary solid shot, which is an elongated cylindro-conoidal projectile of cast iron, about 2½ calibres in length, is comparatively little used now. It is of no use against an armour-plated

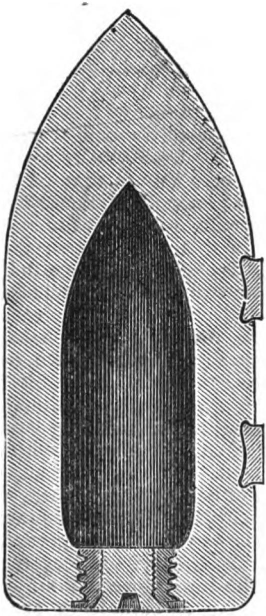
vessel, while against a wooden vessel, or against inflammable material of any description, a shell is much more effective. Therefore ordinary solid shot are used chiefly for practice, as being the cheapest form of rifled projectile available for the purpose. The case-shot differ from those used with smooth-bore guns only in detail. They are provided with segmental zinc linings, to prevent the crushing up of the case into the grooves of the rifling. Some patterns have coal dust between the balls, others sand and clay, to prevent the agglomeration of the balls, or their loss of form, on discharge. For short ranges against the *personnel* of an enemy a case-shot is the most effective projectile known to artillerists. But this effect, on account of the lightness of the balls, and their rapid dispersion, is soon lost, and then the Shrapnel shell comes into play. Of the smooth-bore Shrapnel we have already spoken; of the rifled Shrapnel we shall speak directly.

A more important projectile for the larger rifled guns is the Palliser shot. This may be considered the projectile *par excellence* of our heavier or plate-piercing guns. The Palliser shot is called after its inventor, Major William Palliser. This distinguished officer, who, though not an artilleryman, has done much to improve our artillery material, has the merit of having, in his shot, as in other of his inventions, struck out an original line of his own. At the time when Major Palliser introduced his shot, efforts were being made to find some material suitable for piercing iron plates. The choice seemed to lie between a tough steel and a hard wrought iron. It was generally thought at that time that toughness was one of the elements necessary to success. And this combination of hardness and toughness was exceedingly difficult to obtain, at anything like a reasonable cost and with uniformity. Major Palliser may lay claim to originating the idea that toughness was not necessary at all. All he wanted, he said, was hardness—hardness intense and uniform; and this he found, allied with cheapness, in ordinary "chilled" iron—in iron, that is to say, which had been cast in an iron mould or "chill"* instead of in sand. Great care was necessary in the selection of the iron, and innumerable

* At one time *all* spherical shot were cast in this way, though not with the same object.

experiments were made on this point in the Royal Laboratory. Indeed, even Major Palliser's genius would have availed little without the indefatigable and zealous co-operation of the able manager of that department, Mr. Davidson, who, under Colonel Boxer, laboured for years at this important subject. At last a suitable iron was found,

Fig. 31.—*Section.*



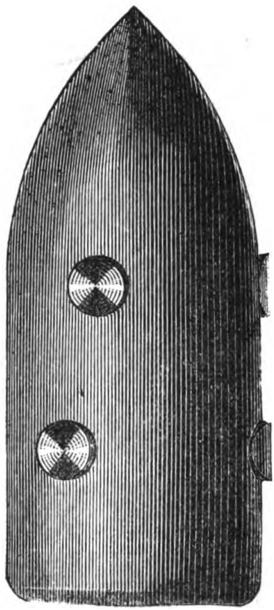


Fig. 32.—*Whole.*

PALLISER PROJECTILES.

and the appliances for casting these shot were brought, under Mr. Davidson's guidance, to great perfection. It must not be supposed, however, that hardness is the only feature in Major Palliser's projectiles. On the contrary, that hardness had to be associated with a particular form oi shot to produce any useful results. A flat-headed or

an obtuse-headed chilled shot shivers to pieces like so much glass on the side of an iron plate. Major Palliser had got the hardness, but with it he had got brittleness. How was this brittleness to be neutralised or eliminated? Up to that time it had been supposed that it could be got rid of only by introducing some toughening element. But, as we have stated, Major Palliser chose another, and an original course. He argued that if he could make his shot of such a form that it would convert the shock of impact into a gradually increasing pressure, he would neutralise the brittleness. He applied this principle by adopting an ogival head, with a radius of from 1¼ to 1½.

Thus the Palliser projectile is not merely a chilled iron projectile, that would constitute in itself no novelty, although chilled iron had never before been applied to the penetration of armour plates; nor is it merely a sharp-pointed ogival-headed projectile. It is a combination of material and form, and in this combination the virtue of the discovery resides. Indeed, we believe that Major Palliser lays no particular stress on the chilling, except as a convenient and inexpensive means to an end. Any hard white-iron shot, made with a Palliser head, would answer the purpose; in fact, some successful experiments have been made with white-iron shot of the Palliser form, the shot having been cast in sand and not in chill. A few words should here be said as to the meaning and effect of chilling. The meaning of chilling is casting iron in an iron mould instead of in sand. The result of such casting is that the metal, instead of being slowly cooled, is quickly cooled, or "chilled," by being brought into contact with a material of high conducting power. In proportion as the cooling is slowly or quickly effected so does the separation of the carbon from the iron proceed more or less completely, slow cooling being favourable to such separation. In proportion as the separation is complete, so will the iron assume a greyer or darker tint, in consequence of the mechanical diffusion through it of the particles of carbon in the form of graphite; while, conversely, in proportion as the separation is incomplete—in other words, in proportion as the cooling is rapid—so will the iron assume a more or less brilliantly white appearance, the carbon being held in chemical combination with the iron.

White iron, as compared with grey iron, is intensely hard and brittle; and Major Palliser's process consists in converting into this hard and brittle material iron which is primarily neither one nor the other, viz., grey or mottled iron. The result, when cast into ogival-headed projectiles, is extraordinarily effective. At comparatively small cost a shot is obtained with which no steel projectile has yet been able to compete, and the effect of these shots breaking up after they have penetrated, and entering the vessel in a shower of splinters, is almost equal to that of a shell, and quite equal to that of a case. At first Palliser projectiles were cast entirely in chill, but it was subsequently found desirable to cast the bodies in sand (so as to avoid exposing too brittle a portion to the shock of discharge), and the head only in chill (so as to obtain the necessary penetrative results.)

Palliser shell differ from Palliser shot only in having a powder-chamber for the bursting charge in the centre. For manufacturing reasons, which need not be here entered into, the shot are now cast with a small cylindrical hollow or "core" in the centre, but the shells have a much larger hollow, and contain from 2 to 15 lb. of powder, according to their size.* The explosion of the powder is effected by the breaking up of the shell on impact on iron plates, no fuze being required. This effects a considerable simplification in the use of these projectiles.

In addition to Palliser shell and shot, our rifled guns fire common and Shrapnel shell, and some of the smaller natures fire segment shell, which latter, however, are gradually giving place to Shrapnel. A few words must be said with regard to each of these projectiles. The common rifled shell is a cylindro-conoidal projectile of cast iron, which is exploded by means of a fuze (either "time" or "percussion") fitted into its apex. The length of the 12-inch shell is about 30 inches, that of the 7-inch about 22 inches—or, roughly, from 2½ to 2¾ times their calibre. In the case of the 10-inch shell the proportion is greater, that projectile being 32 inches (or over three times its diameter) in length. The capacity of some of the larger shells is enormous. Thus, the 12-inch shell takes no less

* A small bursting charge can be used in the cored shot.

than 35 lb. of powder, the 10-inch shell takes 26 lb., the 9-inch 18 lb., the 8-inch 13 lb., and the 7-inch 8 lb. For use at short ranges the 7-inch gun is also provided with a "double" shell—*i.e.*, a longer projectile of increased capacity. This shell contains nearly 13 lb. of powder. It is instructive, as conveying an idea of the enormous increase of shell power due to the use of elongated projectiles, to

Fig. 33.—*Section.*

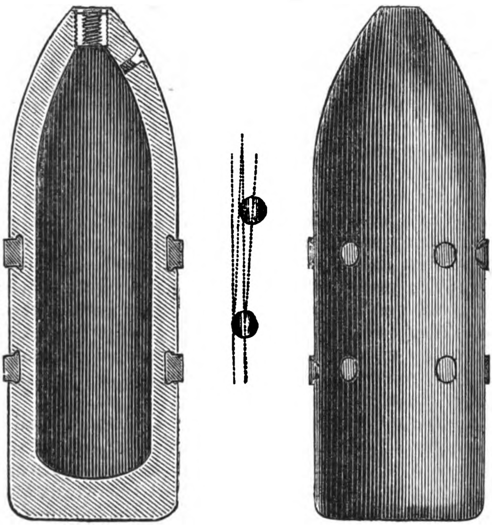


Fig. 34.—*Whole.*

RIFLED COMMON SHELL.

compare the above-mentioned bursting charges with those of the old smooth-bore spherical shell. Thus—

	Rifled Shell.	Smooth-bore
13-inch	32 lb.	10 lb.
10 „	26 „	5 „
8 „	13 „	2¾ „

For use against wooden ships one rifled shell would be as powerful as many smooth-bore shells; and when the greater range and accuracy of the former are taken into

consideration, it will be evident that the importance of the introduction of rifled projectiles as a means of destruction can hardly be overrated. They deal destruction at greater distances, in a larger degree, and with increased certainty, thus fulfilling the fundamental requirements of the artillerist. Against iron-plated vessels, common shells have comparatively little value, on account of their low penetrative power. But if the ship is only very lightly plated, or not plated at all, one rifled common shell may cause her destruction. The moral effect of the explosion of from 20 to 30 lb. of powder inside a vessel is incalculable. We believe it is a fact that the defeat of the *Alabama* by the *Kearsage* was practically completed by a single shell. In the smaller guns, common shells are very useful against an enemy's earthworks, houses, and material generally. By some nations (as the Germans) they are largely, almost exclusively, used against his *personnel.* But such a use seems hardly suitable for common shell; at any rate, greater destruction can be effected in an enemy's ranks by means of Shrapnel and segment, and the Germans have since the late war taken steps to introduce shells of the Shrapnel—or, as we should say, *man-killing*—type.

Before speaking of the rifled Shrapnel shell, it may be well to explain the construction of the segment shell. This projectile, which is now gradually dying out of our service, was the invention of Sir William Armstrong. It consists of a thin cast-iron shell, inside which are built up a number of rows of segmental pieces of iron, like stones in the arch of a bridge, a cylindrical cavity being left up the centre for the bursting charge. This construction gives the projectile very great strength to resist external pressure, whether from the shock of discharge or the shock of impact, or otherwise, while it enables the shell to be opened by a small bursting charge. The internal strength is to the external as the internal strength of an arch is to its external strength. Then, when the shell is opened by the bursting charge, the segments form so many separate missiles, of a formidable and destructive character. In the course of the trials at Dartmoor, in 1869, no less than 1,194 hits of all sorts were obtained with 15 rounds of 12-pounder segments fired against a column of six rows of infantry targets. This is, we believe,

the greatest effect ever obtained with shells of this class, and to this extent it is exceptional. But on many other occasions the segment shell has greatly distinguished itself. A long series of experiments have, however, gone to show that such distinction is likely to be achieved only when the conditions of the practice are peculiarly or accidently favourable. Thus, with a known range, at a column of troops, with plenty of time, with ground especially favourable for percussion fuzes, and with good men to lay the gun, excellent results may be obtained. But such a combination of favouring circumstances is rare, and what is wanted is a shell which will give good average effects under the ordinary conditions of service. This the segment does not do, and cannot do, for two very good reasons :—(1) the bursting powder being in the centre of the shell, it necessarily causes great lateral dispersion of the segments in opening the shell; (2) the segments being made of iron, which, as compared with lead, has a low specific gravity, and being of an irregular form, are not favourable to sustained flight and velocity. These two conditions result in the effect of the segment shell being exceedingly local. A good shell bursting at the foot of a body of men will produce tremendous effects; but let the point of rupture be 20 or 30 yards from the column, and the effect will be at once enormously reduced.

These defects have been remedied in Colonel Boxer's rifled Shrapnel shell, which is an application to the rifled projectile of the construction adopted by him in the diaphragm Shrapnel. The accompanying section of the rifled Shrapnel explains itself. It will be observed that the powder is situate *behind* the missile matter, with which the shell is filled, and which consists of spherical bullets. The size, weight, and number of these bullets vary, of course, with the calibre of the shell. Thus, the 7-inch Shrapnel contains 227 8-ounce balls; the 8-inch contains 376 10-ounce balls; and the 9-inch, 564 12-ounce balls. The 16-pounder shell contains 63 large bullets and 56 small ones; the 12-pounder breech-loading Shrapnel contains 42 bullets, 18 to the pound; and the 9-pounder, 21 of the same bullets. From time to time, as the patterns of the shell alter, these numbers are slightly varied. The above figures are, therefore, given only as exhibiting approxi-

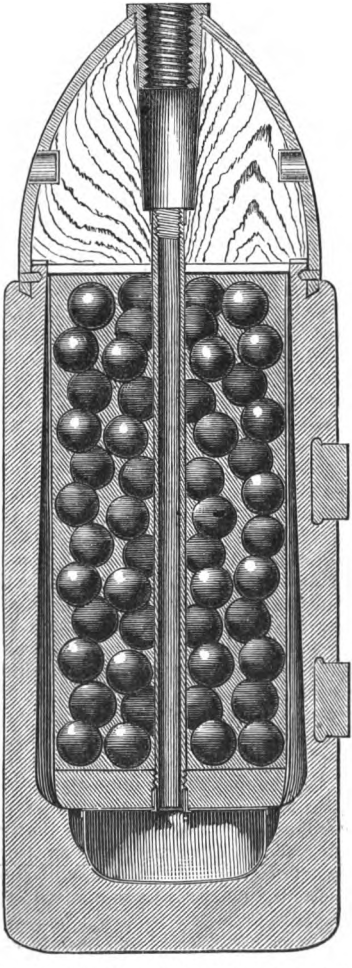


Fig. 35.— BOXER RIFLED SHRAPNEL SHELL.

mately the capacity of shells of this class. As *man-killing* projectiles, the effect of the rifled Shrapnel shell is tremendous. It is intended to be opened at a certain distance in front of the object to be fired at, when the bursting charge, ripping up the sides of the shell, liberates the bullets, which proceed onward in a curved cone, the apex of which is at the point of explosion. On one occasion, at Dartmoor, the 12-pounder Shrapnel, firing nine effective rounds, gave 652 hits of all sorts, of which 374 were "throughs." In the recent trials against the German gun at Shoeburyness the Shrapnel shell more than once greatly distinguished itself. For example, out of 5 rounds fired at 800 yards with percussion fuzes, the effects were on one occasion no less than 103 hits per round, against 33 hits with the German common shell. At 1,500 or 2,000 yards the Shrapnel gave from 30 to 40 hits per round. In the course of the 16-pounder trials, the following results have been obtained. At 1,000 yards, against two rows of targets, 67 hits per round; at 1,500 yards, 82 hits per round; at 2,000 yards, 70 hits per round. These are prodigious effects, particularly when it is considered that to produce them it is not necessary to make a good shot every time—that is to say, the shell may be burst from 50 to 150 yards short of the object with excellent effect, thus giving a large margin of permissible error in the laying of the gun, and in the preparing and burning of the fuze. And the great advantage of the Shrapnel over the segment is, that it can be used with excellent effect with a "time" fuze, as well as with a "percussion" fuze; in other words, it is independent of the character of the ground over which it may be fired; whereas the segment, requiring an accuracy of action not to be obtained in the field with "time" fuzes, can be effectively used only with "percussion" fuzes, and is thus useless over boggy, or very broken, or very soft ground. To discuss the subject of Shrapnel *versus* segment as it deserves, would occupy far more space than can here be allotted to it. What we have said as to the relative merits and performances of the two, will show that both shells are possessed of considerable merit, the Shrapnel having the advantage in general utility and effect.

With these remarks we close our hurried and imperfect

sketch of rifled projectiles. But before closing this chapter, we should wish to make a few remarks upon the subject of fuzes for shells. In the case of Palliser shells no fuze is required, the heat generated on impact being sufficient to fire the powder. But with other shells a fuze is necessary. There are two great classes of fuzes, time and percussion (or concussion). The time fuze is a contrivance for igniting the bursting charge of a shell (whether common, Shrapnel, rifled, or smooth-bore) at any particular *time* after the shell leaves the muzzle of the gun. Various sorts of time fuzes have been proposed, and of

Fig. 36.—*Whole.*

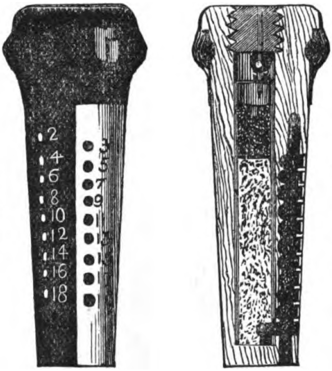


Fig. 37.—*Section.*

BOXER'S NINE SECONDS TIME FUZE FOR MUZZLE-LOADING GUNS.

these varieties several have found a temporary footing in our service. The typical time fuze, however, is the Boxer, in which a cylindrical column of fuze composition (which burns at the rate of 1 inch in 5 seconds) is disposed vertically in a truncated wooden cone. By means of horizontal side holes, placed one-tenth of an inch apart, measuring vertically, the wood can be easily pierced at any required point, opening a vent for the burning composition, which instantaneously flashes down the vertical powder-channel. For example, supposing that the shell is required to burst 2½ seconds after it leaves

the muzzle, the side hole marked 5-tenths (= 5 half-seconds = $2\frac{1}{2}$ seconds) would be bored through into the composition; the flame would come through when the composition had burnt down to that point, and would proceed by a flash down the powder channel to the bursting charge of the shell. Breech-loading time fuzes are made on the same principle, with the addition of a detonating arrangement in the head for igniting them, this being necessary because the fuze cannot, as in the case of the muzzle-loader, be ignited by the flash of discharge.

Percussion fuzes are of infinite variety, and great has been the expenditure of ingenuity and labour, often fruit-

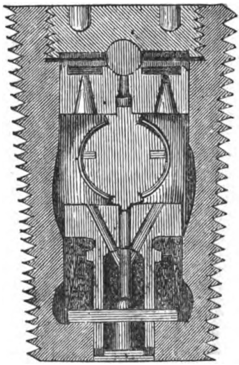


Fig. 38. PETTMAN'S PERCUSSION FUZE.

less, upon their production. They are intended to explode the shell on its striking an object, and without reference to its time of flight. One of these fuzes, the Pettman, may be taken as a type. In this fuze a small brass ball, coated with detonating composition, is enclosed between two supports, one of which rests upon a wire (and a lead cup), which is broken (and the cup is crushed) by the shock of discharge. The ball is thus liberated, and on impact is thrown violently against some part of the interior of the fuze and exploded. The flash passes at once to the bursting charge of the shell. By an ingenious arrange-

ment in the head of the fuze, which our space does not permit us to describe, this fuze may be used for either rifled or smooth-bore projectiles, the conditions of which are different.

But we have dwelt too long, although in one sense not long enough, on the subject of projectiles and fuzes, and must now proceed to another branch of our subject.

CHAPTER XII.

ARTILLERY CARRIAGES.

HAVING already given an account of the various natures of guns which the present state of artillery science recognises as best adapted for offensive and defensive purposes, we proceed to consider the mechanical appliances external to the gun itself, which are designed to complete its efficiency as a tool in the soldier's hand. All such appliances are embodied in the gun carriage, its furniture and accompaniments. These in the field artillery would include the limber, ammunition wagon, and other vehicles; and, in the garrison or naval artillery, the platform or slide on which the carriage is worked.

Too much importance cannot be attached to the object of perfecting the carriage with its equipment: indeed, it is impossible to overrate its value. Upon the completeness of the carriage the gun depends for the due development of its destructive power. We may accept it then as an axiom, that the carriage complete should be so constructed as to qualify the gun effectually to cover with its fire the most extended area of country in the shortest period of time which the surrounding conditions and the highest attainable mechanical skill will render possible. It will be readily understood how large a field of experimental research must have been explored in seeking a satisfactory realisation of these requirements.

To adopt a simple method of classification, all artillery carriages may be included under one of two heads, according as they are intended for "field" or "garrison" service. These two chief denominations divide them-

selves into several subordinate varieties, such as carriages for mountain warfare, for guns of position, and siege artillery—the two first of which are closely allied, as regards general construction, to field artillery carriages proper; and in the third we find some natures assimilating to field, and others to garrison carriages.

The broadside and turret carriages of the Royal Navy, too, in their general features resemble some natures belonging to garrison artillery; though in the former mechanical skill has been necessarily exerted to a greater extent than in the latter, with a view to ensuring, under the more difficult conditions of ship-board, an equally perfect control over the guns with that which is obtained on land.

Without entering too minutely into manufacturing details, it is proposed to review the general principles which must be followed in the construction of the two classes of carriages above mentioned, showing also how in obedience to these principles the present forms have come to be adopted.

CARRIAGES FOR FIELD ARTILLERY.

The principal conditions to be fulfilled in a field artillery carriage are—

1. That it shall furnish a convenient and secure support to the gun, both when in action and when travelling.

2. That it be of a form easily handled and manageable, to give direction to the gun when in action.

3. That it be adapted for rapid movements, in conveying the gun not only over good roads, but also over rough and broken country.

4. That provison be made for an ample supply of ammunition and stores, easily accessible to the men serving the gun; also, that provision be made for the conveyance, when necessary, of a proportion of these men.

5. That its construction shall be sufficiently strong and durable to resist the statical and dynamical strains and varieties of climatic action to which the contingencies of warfare may expose it.

6. That it shall admit of being readily taken to pieces and conveniently stowed on board ship—a condition which is peculiar to the military carriages of our country.

With respect to the first condition, as field guns have trunnions, a very simple form of carriage can be adopted; all that is needful, so far as the connection between the gun and its carriage is concerned, being a frame supporting the trunnions in such a manner as to allow the gun freedom to rotate about their axis through a sufficient angle for any elevation or depression that may be necessary in laying it. This is secured by providing semicircular trunnion-holes on the upper surfaces of two cheeks or "brackets," which are separated above from each other at such a distance as will just allow of the gun working freely between them through certain prescribed angles, and rigidly connected beneath either by cross-pieces termed "transoms," or by a solid block called the "trail," of which more will be said presently. It is highly important that the gun should be elevated and depressed in a vertical plane, this condition being essential to accuracy of fire at long ranges; the common axis, therefore, of the trunnion-holes must be horizontal when the carriage stands upon even ground.

The third and only remaining point of connection between the gun and its carriage is at the cascable, where there is an appliance for elevating and depressing the gun with great nicety, at pleasure. The more modern designs of field guns having little or no preponderance, there is but little strain thrown on the elevating arrangement either in travelling or firing, as compared with that which the trunnions exert upon the brackets. As respects the stability of the carriage, it is evident that it must have at least three points of support for standing securely on the ground. Two of these are at once supplied by the wheels on which the carriage travels, and the most suitable position for a third remains to be determined. On firing the gun, a violent shock or impulse is communicated to its carriage in a direction exactly opposite to that in which the shot travels. The third point of support, then, must necessarily be behind the gun, and so situated as to check any tendency in the carriage either to turn round to the right or left, or to turn over backwards at the moment of firing. To answer the first of these requirements, the point must be selected in the same vertical plane in which the axis of the bore lies, and for the second it must not be

within a certain distance from the trunnion of the gun, this distance being fixed by the angle which an imaginary straight line perpendicular to the axis of the trunnions, and connecting it with the third point of support, makes with the ground-plane. This angle, it is found, should not exceed 21°. If the rear point of support were brought nearer to the trunnions the angle would increase, and with it the tendency of the carriage to capsize backwards on firing. This angle is in effect the limiting angle of friction for field gun-carriages. The rear point, then, is well behind the gun; its connection with the body of the carriage is secured by a substantial beam called the "trail," which is strongly joined to the axletree in front, and rests on the ground behind. All that is needed for the stability of the gun and carriage, when the latter stands ready for firing, is that the vertical line passing through their centre of gravity should fall within the triangle formed by their three points of support. In practice it is found that if the gun is balanced just over the axletree, so that the axes of both trunnions and axletree are nearly in the same vertical plane, the conditions of stability are secured. By this arrangement the pressure of the rear end of the trail on the ground is about one-half of its own weight.

So far, then, as respects the stability of the gun and carriage, both when firing and when ready for firing, the conditions are realised in a two-wheeled carriage provided with a trail of suitable dimensions. The next question for consideration is, how would such a carriage travel? It will be at once evident that, excepting for very light guns, a carriage such as now described on two wheels only would be inadmissible, for this reason—the pressure exerted by the trail on the ground when in the firing position, would when travelling have to be sustained by the horse; and in the ordinary descriptions of field-carriages the weight and unwieldiness of the trail alone would be a serious objection to such a method of draught, and the means of attaching and detaching the horses would be correspondingly clumsy. We conclude, then, that a gun-carriage provided merely with two wheels and a trail body, while exhibiting an excellent combination for firing purposes, is altogether ill adapted for travelling, excepting when applied to very light artillery such as that designed

for mountain service. Here a proportionally light carriage is needed, to the trail of which a pair of shafts can be readily attached, their combined weight being supported with ease by the draught animal, which is generally a mule.

In the field artillery, therefore, an additional pair of wheels for the support of the end of the trail becomes necessary when travelling, and the result is a four-wheeled carriage. It so happens that the construction we have seen to be very suitable as a standing carriage, offers great facilities of being converted at will into a simple and efficient form of travelling carriage. All that is needed for this purpose is to procure an independent fore-carriage to which the horses are harnessed. Attached to the centre of the hind part of this carriage is a strong hook. To the end of the trail of the gun-carriage proper must be fitted a suitable iron loop. This is known as the "trail eye." Lifting the end of the trail off the ground to a height just above the level of the hook on the fore-carriage, the hook is brought under the trail eye, which is then lowered down into it, and secured by a horizontal key which passes through the end of the hook. We are thus provided with a strong and well constructed four-wheeled carriage. The fore-carriage is known as the "limber;" the process of connecting the trail with it is called "limbering up" (Fig. 39), the converse of which is "unlimbering." The limber, whether attached to the gun-carriage or acting independently, is equally available for movement. In one case it acts as a fore-carriage, in the other as a cart, so far as the arrangements for travelling are concerned. The shafts, which are rigidly connected with the body of the limber, take a share with the wheels in supporting its weight and maintaining it in the proper travelling position. When the carriage is unlimbered, the weight on the shafts is rather excessive, but this is counteracted when in the travelling position by the weight of the trail acting on the hind part of the limber, and thus counterbalancing the otherwise great preponderance on the shafts, which would act injuriously on the shaft-horse. It is not contemplated that the limber should be required to travel far when detached from its gun-carriage. The undue weight on its shafts when thus detached is therefore a matter of little moment.

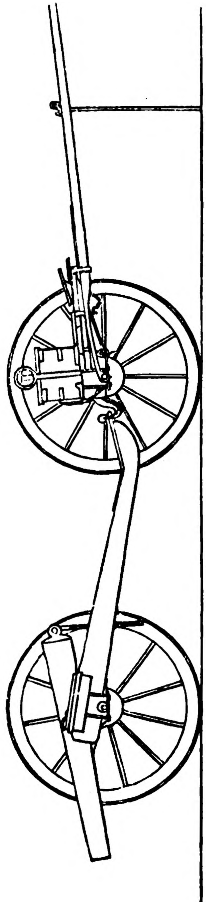


Fig. 39.—FIELD CARRIAGE LIMBERED UP.

We have seen that in order to secure stability in the firing position a certain length of trail is indispensable, and that the entire weight of gun and carriage must be so distributed as to bring upon the point of the trail about half its own weight. As the trail must be lifted by hand for the purposes of limbering up and unlimbering, the weight to be raised should be restricted within the lowest limits compatible with the requirements of stability and strength; its length should therefore not exceed these limits, and its weight must be no greater than what is

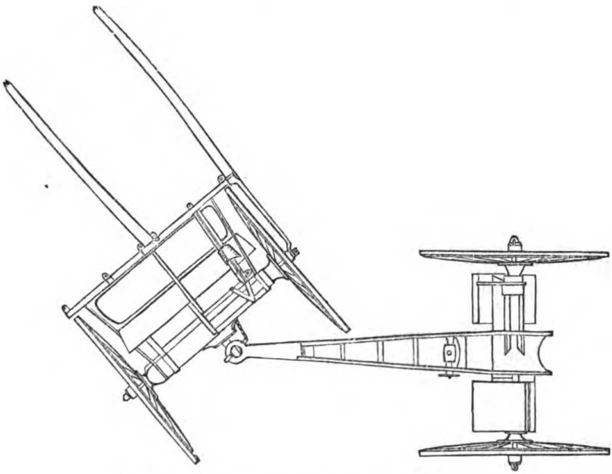


Fig. 40.—PLAN SHOWING AMOUNT OF LOCK.

necessary to ensure sufficient strength to resist the shocks incurred in travelling and firing. In the construction of every kind of vehicle, the minimum of weight consistent with a necessary reserve of strength is the object desired. These properties, lightness and strength, are primarily antagonistic; and the form adopted is in effect that to which science and experience point as being the most effective compromise between them. Again, the length of the trail must be sufficient, and only sufficient, to admit of

a free passage between the wheels, in order to gain access to the trail-eye and limber-hook. The space between the front and hind wheels is, of course, dependent upon the length of the trail. It is essential also that the carriage should be short, both on account of covering as little ground as possible when turning, and in order to diminish as far as practicable the length of a column when marching along the road.

Regarded on its merits as a four-wheeled vehicle, one point is especially worthy of notice in the field carriage. The form of the gun and its particular functions admit of the trail being made extremely narrow, assimilating to the perch of an ordinary carriage. This construction, without sacrificing the advantages secured by a high front wheel, affords ample facility for changing direction. The limber can be turned to the right or left, about the trail-eye, as a centre, through a considerable angle before its wheel comes in contact with the trail, as in Fig. 40. Thus it will be seen that this form of carriage claims for itself almost exclusively the following advantageous combination :— 1. A low body. 2. Good locking power. 3. High front wheels. This combination secures pre-eminently the all-important qualities of stability in travelling and handiness in turning ; also a further advantage, which will be presently considered as fulfilling in a great measure the third essential condition which was stated in the onset—namely, the capability of rapid movement.

With reference to the second condition, requiring that the gun should be handy when in action, the two points to be considered are—(1) facility for turning the gun horizontally ; (2) in a vertical direction. 1. To turn the gun horizontally, to the right or left, there is an iron staple or shoe fixed upon the end of the trail just above where it rests on the ground. Into this shoe a handspike, which is always carried with the carriage, is stepped, and is so curved that its point or handle shall be raised to a convenient height for a man to take hold of when standing by it. One man is able with tolerable ease to lift the weight of the trail sufficiently off the ground to enable him to move it either to the right or left, causing the gun to turn horizontally about an imaginary vertical axis, equidistant between the wheels, thus giving any horizontal direction

that may be required. 2. The vertical direction, or elevation, is obtained by raising or depressing the cascable. This is effected by an elevating screw, the upper end of which is attached to it, and which works in a female screw below, made to revolve by means of a small hand-wheel worked on the right bracket of the trail. The gearing is so constructed that a very slight effort with one hand suffices to raise or lower the gun.

With regard to the third condition—namely, the adaptability of the carriage to rapid movement—it has already been observed that high wheels can be used; we will now proceed to illustrate the advantages which they confer. High wheels, if not very ponderous, contribute greatly towards easing the draught. This they do in a twofold manner, first by diminishing friction, and secondly by spanning ruts and hollows on the surface of the road in such a way as to offer less resistance than smaller wheels would offer to the progress of the vehicle. It has been proved by experiment, and is capable of mathematical demonstration, that the traction or pull of the trace is diminished by increasing the height of the wheel. The ease with which horses can draw a carriage increases *with*, though not *as*, the radius of the wheels. If, for instance, a horse harnessed to a cart with wheels of fifteen inches radius draws the load with a pull on the trace amounting to twenty pounds, the pull on the trace would not be halved by doubling the height of the wheels—giving them a radius of thirty inches—but it would be very materially diminished. On ordinary roads, where a succession of trifling obstacles are encountered and surmounted by the wheels, the pull of the trace would be reduced probably from twenty pounds to thirteen pounds by doubling the height of the wheels. Hence, though the advantage to the draught is not directly proportional to the height of the wheels, it is nevertheless very greatly dependent upon their height; and thus it is highly important to maintain the wheels of field artillery carriages at the greatest diameter which the limits of convenience and moderation in weight will permit. The experience of the British artillery has given a sanction to five feet as being the most suitable height of wheel for the artillery service; and with this height of wheel the limber can lock round

through an angle of about 52°, giving the carriage abundant facility for turning on ordinary roads, and in manœuvring on the field. This advantageous combination of a high front wheel with a good lock is simply due to the narrowness of the trail, which when the gun is limbered up may be said to take the place of the body of an ordinary wagon.

If we turn for an instant to the construction of ordinary wagons, the difficulties involved in securing this combination will perhaps be more readily seen. Nearly every wagon used on ordinary roads at the present day is furnished with front wheels which pass freely under the body—a standing acknowledgment of the importance of good locking power. In order to secure this, however, whilst maintaining a tolerably low position of the body, the front wheel must also necessarily be low to pass under it, very much lower than the hind wheels, the position of which relatively to the body never alters. Now, on the excellent macadamised roads of England, a low front wheel, though objectionable, is not of so very much importance, especially when the wagon is on springs. The first two points of the combination before mentioned are secured; the third is sacrificed. Experience has proved this arrangement to be the best suited for ordinary traffic on good roads. For military service, however, the circumstances are widely different. The carriages accompanying an army in the field must often follow the worst of roads, and not unfrequently across country. Every contrivance, therefore, by which the draught can be lessened must be carefully studied. It is accordingly highly fortunate that the peculiar construction of the gun-carriage does not necessitate a low limber-wheel.

The fourth essential condition is secured by carrying thirty rounds of ammunition complete in two boxes, which are placed on the limber. In addition to these four rounds of case-shot are carried, in two small boxes, on the axletree of the gun-carriage. Each gun is accompanied on service by an ammunition wagon, consisting of a "body" and a limber, which latter is identical and interchangeable with the limber of the gun-carriage. The wagon-body has a perch made of girder-iron riveted securely to the axletree-bed. This perch occupies the place of the trail

in the gun-carriage, and, like it, is attached by an eye to the limber-hook. The wagon-body has four ammunition boxes, and its limber two, each containing fifteen rounds of ammunition, making in all ninety rounds. Thus each gun-carriage, accompanied by one wagon, has a supply of 124 rounds of ammunition. This quantity is considered ample for immediate wants, reserves being always in readiness to replenish the wagons as they become exhausted. The limber-boxes are fitted as seats for the conveyance of two, or possibly three men on each limber. In the horse-artillery the remaining members of the detachment serving the gun are mounted. In the field artillery they march on foot except on emergencies, when two additional gunners sit on the axletree-boxes of the gun-carriage, and others can be mounted on the off-lead and centre horses drawing the gun.

With reference to the fifth condition, it will suffice to say that the dimensions of the various parts of the gun-carriage have been arrived at through the experience of actual warfare, combined with careful calculation. Excepting in the spokes and felloes of the wheels, and the axletree-beds, foot-boards, and bottom-boards, no timber takes any part in the construction.

In the gun-carriage the brackets of the trail are made of plate iron, with angle-iron framing. The body of the limber, excepting the axletree-bed, is also of wrought iron.

By a judicious disposal of the iron, the requisite strength is secured without excess in weight. The weight of the 9-pounder gun-carriage and limber packed complete is about 35 cwt. As to durability, it may be affirmed that, with attention to prevent rusting, the carriages and wagons are in all their main parts practically indestructible.

With respect to the sixth and last condition—namely, that of packing on board ship—the ammunition boxes are readily removed; and when the carriages, limbers, and wagons are dismounted from their wheels, an entire battery can be stowed away in very little space, considering the large quantity of stores it includes.

Reverting to the fourth condition, it may be as well to state that every convenience for carrying side-arms, intrenching tools, and small stores is applied both to gun-carriage and wagon with their limbers; and, indeed, up

to the present time a full complement of tents for the accommodation of each gun detachment has been carried on the wagons—an admirable arrangement, and one highly conducive to the comfort and health of the soldier.

CHAPTER XIII.

CARRIAGES FOR GARRISON ARTILLERY.

THIS class of ordnance, as its name implies, is intended for the armament of permanent forts and batteries, which, being usually constructed long before the approach of an enemy, are furnished at the will of the occupier with guns of the heaviest and most destructive nature.

Prior to the introduction of armour-plating in ships and forts, the heaviest garrison-gun was the 68-pounder, of 112 cwt. Now we have rifled guns of seven, nine, twelve, and twenty-five tons commonly supplied for this service; and so far as the working of the gun is concerned, there is no reason for limiting its weight to 50 or even 100 tons. It will be at once obvious that the fixed positions to be occupied by these guns, and their increased weight, impose great modifications in the make of their carriages, as compared with those for the field artillery. Thus the third condition stipulated with respect to these latter (*vide* preceding chapter) is that the carriage shall be adapted for rapid movement, a condition quite inapplicable to garrison service. So, also, portions of the first and fourth conditions, relating to travelling and to the conveyance of the gun-detachments. The sixth, too, as to convenient stowage on board ship, becomes a point of third-rate importance, it being presumed that the arming of our fortresses across the sea admits of being carried on gradually, and not during a war pressure. On the other hand, the extreme accuracy of artillery fire from rifled guns imposes a fresh condition on the carriages for our garrison artillery, which, being stationary, naturally present a tempting object for an enemy's fire if greatly exposed to view.

The chief conditions to be fulfilled in a garrison gun-carriage may be thus stated :—

1. That it shall furnish a convenient and secure support to the gun, both when in and out of action.

2. That it shall be of a form easily under control, and adapted for giving accurate direction to the gun when in action.

3. That its construction shall be such as to admit of the least possible exposure to the enemy either of gun, carriage, or men working them.

Taking the first of these conditions, the trunnions, which are common to all guns, field, garrison, and naval, allow of the same general arrangements for garrison carriages as for those of the field artillery. Semicircular trunnion-holes sustain the gun, which can revolve freely in a vertical plane for purposes of elevation and depression. They sustain the greater part of the shock when the gun is fired; consequently the "cheeks" or "brackets," into the upper surfaces of which they are cut, must be very strong. In the old smooth-bore carriages (Figs. 41, 42) these brackets, A A, are of oak. They are rigidly held apart at a distance suitable to receive the gun between them, and are connected by a stout oaken block, B, called a "transom," which is inserted, or "housed," into the inside surface of each bracket, and is bolted securely to them. The brackets are further secured in a similar manner by front and rear axletrees, or by a front axletree, C, and a rear "block," D, all of which are made of oak.

All natures of smooth-bore guns have considerable preponderance, their centre of gravity being, in other words, well behind their trunnions; hence, a third point of support must be found for the gun towards its breech. This is supplied in the simplest constructions by a "quoin," E, which is a wedge-shaped piece of wood, placed immediately under the breech, and resting on a block, F, called a "stool-bed," the front part of which is hinged to a horizontal bolt, the hind part being supported by the head of an elevating-screw, G, which is held and works up and down in the rear block. Thus, the gun is securely supported in its carriage. This latter is supported on the ground either by four low iron trucks working on the axletree arms, or

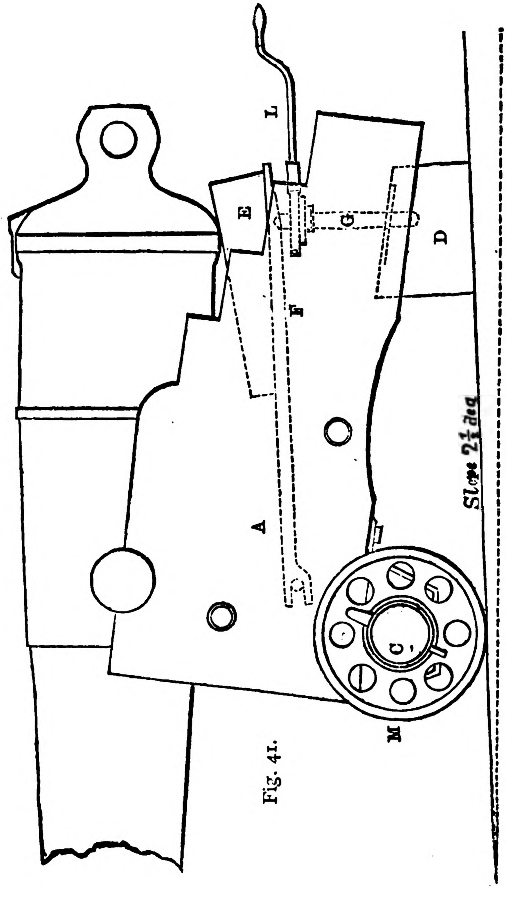
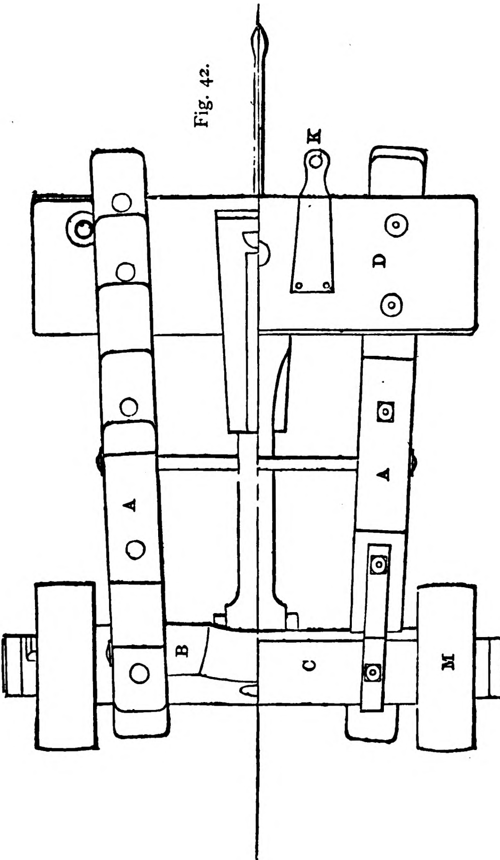


Fig. 41.

Fig. 42.



by two front trucks, M, and a rear block, D. This block rests on the stone platform prepared for the carriage. The centre of gravity of gun and carriage is well within the four points of support thus furnished, so its stability, when not in action, is assured. When in action, however, the same law which necessitates a certain length of trail in the field gun-carriage is equally operative in all ordinary garrison carriages. The angle which a straight line drawn from the axis of the trunnions perpendicularly to it, in the direction of the rear line of support, makes with the ground-plane or platform must be kept within certain limits, to prevent the carriage from turning over backwards when the gun is fired. This angle need not be so small with garrison as with field carriages, the platforms on which they recoil being comparatively even and regular.

Passing on to the second condition, the simple form of carriage we are now considering will be found defective in facilities for laying the gun correctly under certain circumstances. The carriage, as has been already stated, stands on a stone platform. This platform is not laid level, but is given a slope towards the front, or parapet, of about 2½ or 3 degrees, a construction which much assists the working of the gun, and prevents excessive recoil on firing—in fact, so controls the carriage as just to bring the muzzle of the gun sufficiently behind the parapet to admit of loading at the muzzle with ease. After the gun is loaded, it must be run forward so as to bring the muzzle into the embrasure, and well in front of the interior slope of the parapet, before it is fired, otherwise the force of the explosion would act destructively upon the work. In this operation the slope of the platform renders valuable aid. By means of a roller-handspike, H (Fig. 43), which is placed under a socket, K (Fig. 42), the rear block of the carriage is lifted just off the ground. The carriage may then be said to be on three wheels, namely, the two front trucks, and the roller of the handspike. Then, favoured by the slope of the platform, a very slight impulse suffices to move it forward into the firing position. A lateral motion, which can also be given to the hind part of the carriage in turning the roller-handspike either to the right or left,

will, with the assistance of common handspikes, give the necessary horizontal direction to the gun; or this object can be obtained solely by the leverage of common handspikes applied under the rear of the brackets. The vertical direction is given by means of the elevating-screw, G (Fig. 41), worked by the lever-arm, L (Fig. 41).

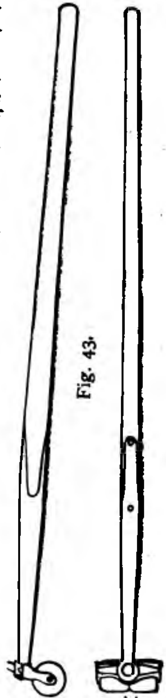


Fig. 43.

This form of carriage, while commending itself on account both of simplicity and in working, is only suitable for guns not exceeding 3 or 3½ tons in weight (heavier would prove unwieldy), and occupying positions where the lateral direction of fire at long ranges is circumscribed. The necessity for thus limiting the lateral direction is owing to the deviation of the line of sight from the line of fire when the distance of the object renders some elevation above the line of sight necessary to prevent the shot falling short. This so-called elevation is always given in a plane at right angles to the axis of the trunnions by means of a tangent scale attached to the breech of the gun, and working in that plane. If, then, when firing at elevations above the direction of the object, the axis of the trunnions happens to be out of the horizontal, the divergence of the line of fire from the line of sight will no longer be vertical, and some horizontal error ensues. This error increases with the elevation of the gun, the inclination of the trunnion axis, and the length of the range. The exact amount of lateral deviation, in linear measurement, from the object aimed at, is obtained by means of trigonometrical expression, in which the known quantities are the length of the range, the inclination of axis of trunnions, and the nominal elevation of the gun. It has been said that carriages of the class under con-

sideration stand on ground platforms which slope at an angle of $2\frac{1}{2}^\circ$, or thereabouts, towards the front of the work. If, then, the gun is fired in a direction either to the right or left of this front, one of its trunnions will be thrown above the other, and if firing at long ranges and high elevations, the error admitted becomes important. For example, let us suppose a nominal elevation of 7° given to a 32-pounder smooth-bore gun directed at some object 2,500 yards away, the line of sight making an angle of 30° with a line perpendicular to the front of the embrasure, the slope of the ground platform being $2\frac{1}{2}^\circ$; then the real error admitted will be found to amount to about forty feet, that being the distance which the shot would fall either to the right or the left of the object. So serious an error cannot be disregarded; consequently, where breadth and length of range combined are required, some more perfect arrangement must be resorted to. In providing flank defence for ditches and faces of works within short range, this carriage is very suitable; also for long ranges, where the line of fire is confined almost to the direct front. It is not intended to carry the heavier natures of garrison guns; in fact, the 64-pounder rifled gun and the 32-pounder and 8-inch smooth-bores are as large as can be efficiently worked on these carriages. For guns of heavier metal, greater facilities in the processes of running up and of altering direction must be obtained, and a special mechanism is designed for communicating horizontal angular motion. The sloping platform on which the carriage recoils is itself made to revolve on a horizontal plane, round a pivot situated either in or behind the parapet. This pivot may be either in front, behind, or in the very centre of the platform, according to the width of range required of the gun, and architectural considerations. For instance, if the gun is to occupy a casemate, and to fire from an embrasure, that position of pivot which will give the greatest horizontal range will be in the embrasure, and under the front part of the gun, when the latter is run out to the firing position. If, on the other hand, the gun is intended to cover a wide extent of ground, firing over a high parapet, no better position of pivot could be chosen than the centre of the platform. These platforms for the lighter classes of guns are strongly

built of timber; but for guns of seven tons and upwards, all platforms are of wrought iron (see Figs. 44, 45, p. 120). Every platform stands on four low iron wheels, or "trucks," A A, so formed and attached to it as to roll on horizontal iron bars curved in the form of arcs of circles, the pivot forming their proper centre. These bars or "racers," as well as the pivot, are firmly bedded in masonry. As the gun-platform revolves upon these horizontal racers, the trunnions are kept also horizontal, whatever the direction given to the gun. Thus the error pointed out as occurring in certain cases with the sloping ground-platform and common standing-carriage, is at once removed. It has just been said that sometimes the pivot is in the embrasure, and beneath the front part of the gun when in the firing position, as in Fig. 42, p. 115. Then, however, it is *imaginary*, not real, which it would be if situated anywhere else.

A real pivot would be inadmissible in this exceptional position, as no rigid connection between it and the platform could be secured without greatly weakening the face of the work. It is, of course, advantageous to use real pivots when practicable. In using the imaginary, or "A" pivot, as it is called, the trucks are kept on the racers solely by flanges similar to those with which the wheels of railway carriages are made. When material pivots are used, they are an important auxiliary to the flanges in securing the platform on its racers. The plane of revolution being horizontal, the platform is favourably placed for movement with the object of giving lateral direction to the gun. By the aid of tackle hooked to the platform at one end, and at the other to an iron loop suitably placed in the masonry, sufficient power is obtained for traversing the heaviest guns; but with them the operation is slow, and it has been deemed expedient to correct this want of speed by substituting a toothed-wheel system of "traversing gear," attached to the platforms, in place of the original tackle. The principle upon which it communicates motion to the platform is by causing the trucks to revolve, the power being applied at one or two winch-handles working in the rear of the platform, and being increased to the extent which experience has proved

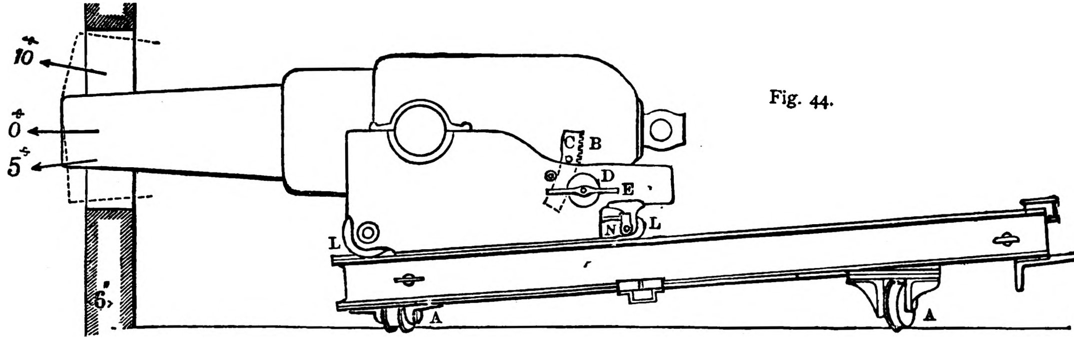


Fig. 44.

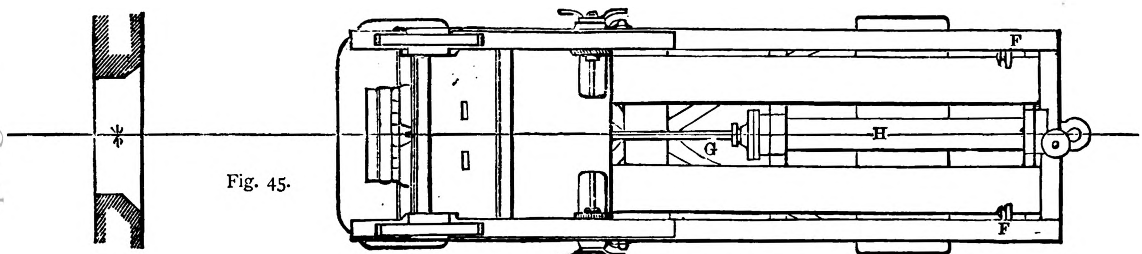


Fig. 45.

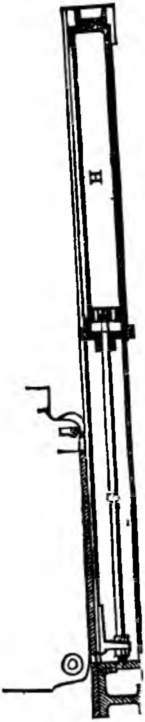


Fig. 46.

to be most efficient, by a system of pinions and wheels interposed between the winch-handles and the trucks. The horizontal direction is thus given to the gun rapidly, and without the admission of any error such as we have seen to obtain, under certain conditions, with a common standing-carriage working on a ground-platform. With respect to vertical direction, the necessary motion is imparted to the heaviest natures of guns by simple mechanism which, as with the lighter descriptions of ordnance, is attached to the carriage. A toothed arc of iron, B (Fig. 44), is connected with the gun on each side by a pin, C, about which the arc is free to revolve. These arcs are geared into pinions attached one to each bracket of the carriage. The pinion is rigidly connected with a short shaft or spindle, which passes through the bracket from its inner to its outer surface. Here it is fastened to an iron disc called a capstan-head, D, round the periphery of which a number of holes are drilled, for the purpose of receiving one end of an iron-pointed lever, at the other end of which the power is applied, causing the capstan-head, and consequently the pinion, to revolve, thus moving the arc up or down, and with it the breech of the gun, which, revolving about its trunnions, attains the required elevation or depression, and is held in position by means of a screw jamming-lever, E, which clamps the capstan-head against the bracket. The motion thus given is sufficiently powerful and rapid, but is scarcely so delicate as might be desired for the highest accuracy in laying. The clamping arrangement, too, has at times been found ineffective. On this account the following modification has been tried, and has been

found to remove both defects. A worm wheel is substituted for the capstan-head; into this an iron worm, attached to the outside of the bracket, is geared. The shaft on which the worm is fixed is furnished with a hand-wheel so placed as just to clear the top of the rear portion of the bracket. No special clamping arrangement is needed.

It is necessary to control the recoil of the gun and its carriage, so that they shall be stopped before reaching the end of the platform; for if the carriage came violently in contact with the stops, F, F, fixed at the extremity of each side of the platform, the various parts of the structure would soon become greatly strained, rendering the gun liable to temporary disablement. Various expedients have been resorted to for absorbing the recoil, some by means of friction, applied either before or immediately after its commencement, and continued with a constant resistance until the carriage is brought to rest: the compressor, which causes the friction by means of screw power, being attached to the carriage; and the balks of wood or bars of iron on which the compression is applied being laid longitudinally from front to rear of the platform, with which they are strongly connected at both ends.

Another application of friction has been designed, with the object of gradually increasing the resistance from nothing at the instant of firing until the motion of the carriage is arrested. This is attained by interposing between the compressor and the bars compressed some elastic medium, such as india-rubber or steel springs, and making the bars wedge-shaped in horizontal section, the wider end being at the rear of the platform. Thus, as the carriage recoils, the compressors, recoiling with it, and being fixed apart at a constant distance, carry with them the sheet india-rubber or steel spring, which undergoes a gradually increasing compression or deflection as the balk increases in width; the pressure, and therefore the resistance, increasing proportionately.

Another method of checking the recoil, and one which has been generally introduced with great success, is by means of the resistance offered by a considerable body of water, or other fluid, when forced through a small

opening. The contrivance was originated by Colonel Clerk, of the Royal Artillery, late Superintendent of the Royal Carriage Department. It commends itself on the grounds of simplicity and effectiveness, consisting merely of a piston, G (Figs. 45, 46), attached to the bottom of the carriage, having four holes of about an inch in diameter in the piston-head, the diameter of which is about eight inches. This works in a cylinder, H, fixed along the centre of the platform, and which, being otherwise closed at both ends, is nearly filled with oil. On firing the gun, the recoil forces the piston-head against this confined mass of oil, which can only make way for the progress of the piston by escaping through the openings in its head, thus presenting a great resistance to the motion of the carriage with which the piston is connected. This resistance, unlike that of the frictional compressors, is greatest almost at the first instant, and rapidly decreases, varying with some power of the velocity of recoil, probably between the square and cube of that velocity. A merit possessed by this "hydraulic buffer," as it is termed, is the superior regularity of the resistance offered by a fluid compared with the resistance due to the friction of two solid surfaces.

After each recoil of the carriage, the gun is in a convenient position for loading. This process completed, it remains to be considered what facility is offered for running the carriage forward into the firing position. The carriage in its usual position is supported by the platform, on which the brackets rest along their entire length. In recoiling, very great friction is set up between the touching surfaces of the carriage and platform. This friction materially assists in bringing the carriage to rest. The resistance may be estimated at one-tenth of the weight moved. The 9-inch gun and its carriage weigh about 15 tons, consequently the resistance due to friction will be about one ton and a half. Useful as this is in recoil, its action presents a serious obstacle to running up the gun into the firing position, which would have to be accomplished by manual labour. The difficulty is overcome by the simple expedient of raising the sides of the carriage off the platform, and supporting them on rollers, L L (Fig. 44). The front rollers are so attached

to the carriage, that they shall, under ordinary circumstances, be just clear of the platform. The hind rollers work on eccentric axles, so adjusted that until the eccentric axle is turned round by a lever inserted in the socket N, which is rigidly connected with the axle, the roller takes no bearing on the platform. When that operation is performed, however, the rear rollers raise the whole carriage, bringing its front portion on to the front rollers. The carriage is then, for the time being, on four wheels, and its gravity acting down the slope of the platform impels it towards the front.

The various contrivances now described provide for the heaviest guns being controlled effectually and rapidly.

With reference to the third condition, a few words must suffice. Artillerists have long directed their attention to the object of securing the best possible cover for gun, carriage, and men. Three distinct methods have been suggested. The first by reducing the size of the embrasure to its smallest possible dimensions. With this view, the system of racers, with imaginary pivot under the muzzle of the gun, was introduced, admitting the use of a narrow but high embrasure. This has been in some cases greatly reduced in height by the introduction of muzzle-pivoting carriages, several varieties of which have been tried; and some few are adopted for service in naval turrets. The distinctive feature of these carriages is that the gun receives its elevation and depression partly or entirely by moving the trunnions down or up, while the position of the muzzle remains stationary. The second method is that of utilising the force of recoil to raise an iron shield in front of the embrasure. This has never been adopted, but seems practicable and well deserving a trial. The third method is that of having a very high parapet, over which the gun fires, and under cover of which it is loaded. The very ingenious invention of Captain Moncrieff, now so well known, is at present the only successful representation of this method. In his system he utilises the force of recoil to bring the gun under cover; and by the action of a counter-weight restores it to the firing position.

CHAPTER XIV.

BALLISTIC INSTRUMENTS.

A BRIEF description of the instruments which have from time to time been invented to determine the velocity of projectiles is proposed to be the substance of this chapter. To clear the subject a little, it will be necessary to explain some of the advantages which may arise from knowing at what rate projectiles are moving through the air. The greater velocity any projectile has (*cæteris paribus*), we get—(1) greater range; (2) flatter trajectory; (3) greater penetration and destructive effect; (4) greater accuracy of shooting; in fact, four points which are of the greatest importance in artillery or rifle practice.

The maintenance of the velocity of the projectile over a certain distance depends on the amount of resistance experienced by it from time to time in its passage through the air; the greater the resistance, the greater is the loss of velocity, and *vice versâ;* so that it becomes a problem of considerable interest to determine experimentally what the actual resistance is to differently shaped projectiles, when moving with different velocities. For instance, you might get a high velocity with a spherical ball, and yet it might be inferior for an extended range, on all the four points mentioned above, to an elongated projectile fired with a lower velocity out of the same gun, chiefly for two reasons: (1) the increased resistance it actually meets with in its passage through the air; (2) the decreased weight which renders it less able to overcome the resistance of the air. So that supposing the two projectiles were started at the same instant, the spherical projectile would go ahead for a short distance, but would soon be overtaken by the elongated projectile, and finally strike the ground at a much shorter distance from the starting-point.

Let us now proceed in the description of some of the most successful of the instruments which have been devised for measuring the velocity of projectiles.

The ballistic pendulum was the instrument which gave the most practical results before the discovery of electro-

magnetism; and Dr. Hutton, Professor of Mathematics at the Royal Military Academy, Woolwich, made a series of experiments from 1775 to 1791, from which he deduced his law of the resistance of the air, which, although it fails for low velocities, yet for velocities above 1,300 feet-seconds gives a fair representation of what actually takes place for spherical shot. Considering the roughness of the instruments, it is remarkable that such good approximate results should have been obtained.

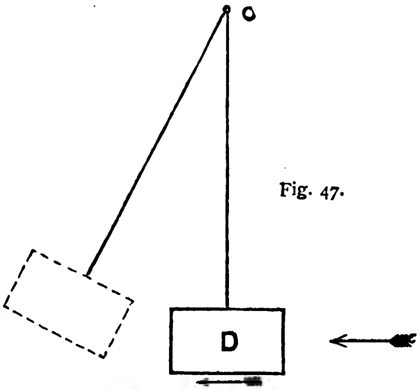


Fig. 47.

The ballistic pendulum (Fig. 47.) consisted essentially of a receiver, D, commonly filled with sand, connected to the point of suspension, O, on which it could turn freely like an ordinary pendulum. The projectile was fired into this receiver, thus imparting the whole of its momentum to the pendulum, which recoiled through a certain angle varying with the velocity and weight of the projectile. This angle was carefully read off by means of a graduated arc attached to the instrument; whence, by a mathematical calculation, the velocity of the projectile at the point of impact was determined. The suppositions on which these calculations depended could never be *strictly correct;* hence the results obtained could not be regarded as anything better than an approximation to the truth.

For instance, it supposes that during the penetration of the projectile into the sand the pendulum remained at rest, and also that the direction of the blow acted horizontally. There was also difficulty in striking the pendulum, so that there should be no vibration for impulse on the axis of suspension. As the distance from the gun increased, these difficulties became almost insurmountable. These defects, as well as the expensive and unwieldy character of the machine, pointed to the desirability of contriving a simpler and more portable instrument to effect the same object.

Major Navez, of the Belgian service, was the first who succeeded practically in obtaining the velocity of projectiles by means of electricity. The instrument he devised was called the electro-ballistic pendulum, the pendulum being used to measure time instead of the force of the blow, as in the former instance.

This pendulum is capable of revolving about a horizontal axis through the point of suspension. A galvanic current circulates through an electro-magnet in the instrument, and through the screens, which are made of thin copper wire. When the current is circulating through the electro-magnet, the bob of the pendulum is raised up to its highest point, and kept there by magnetic attraction; and when the current is broken by the shot cutting the wire in the first screen, the electro-magnet becomes demagnetised, and the bob falls by its own weight. When the shot reaches the second screen, it cuts a wire through which another galvanic current is circulating, and consequently demagnetises a second electro-magnet which had been supporting a small weight. This weight in falling completes a third galvanic current, which sets in action a third electro-magnet, thus clamping a light index which had been travelling with the pendulum from its position of rest. The position of this index is read off on a graduated arc, and indicates the angle through which the pendulum had moved when the third galvanic stream was closed.

Another instrument called a "disjunctor" is used to break simultaneously the wires in the two screens, and the position of the index is read off as before to eliminate the errors of the falling weight, etc. etc., so that the difference between these angles represents, when converted into

time, the actual interval which has elapsed during the passage of the shot from the first to the second screen. This being a certain measured distance, the actual velocity in feet-seconds is easily calculated.

Colonel Leurs introduced some modifications into this instrument, which have improved it considerably, making the observations obtained by it more reliable. He made use of two pendulums, one of which carries with it a registering needle, attached to a washer at the axis. The right-hand pendulum is provided with an arc of a circle, having the axis for its centre, upon which slides a steel strap and thumb-screw. Two springs are so arranged that when the right-hand pendulum falls the steel strap strikes the end of a lever, and releases the two springs, which at once close on the washer of the needle and fix the latter in position. The distance from the strap to the stem of the pendulum determines the position of the needle on the graduated arc, when the disjunctor is used. The difference between the length of this arc obtained with the disjunctor and the arc registered by the needle in actual trial, is the arc required. This modification of the instrument is usually called the "Navez-Leurs."

In the Navez and Navez-Leurs instruments, the time is measured by the arc passed over by a pendulum. This method of measurement is liable to *variation*, and a scientific committee of reference appointed by the War Office has reported as follows :—"The time of describing any given arc is, of course, affected by friction ; and in order to take this into account, the time of describing the same arc by a simple pendulum unaffected by friction is multiplied by a factor, the value of which is found by observing the instrumental measures which correspond to intervals of time which are known *à priori*, such as the time of a body falling freely through a given small space. It is found, however, that the *value* of this factor is *very sensibly different* for different parts of the arc of oscillation of the pendulum. Practically the factor is determined by means of falling weights with which the instrument is furnished, for a considerable arc, beginning a certain distance below the starting-point of the pendulum, then for another considerable arc beginning where the former ended, and similarly for a third ; and in the conversion of an arc

actually observed in the use of the instrument into time, the different values thus obtained are applied to the corresponding parts of the total arc described by the pendulum. On account of the very sensible variation, of the factor, it may be doubted whether this mode of converting arc into time possesses a degree of exactness answering to the delivery of the instrumental indications. Thus, while indications nearly equal to each other may be compared by means of this instrument with great accuracy, we do not think that quite the same confidence can be placed in its determinations of *absolute velocity*, or of *relative velocity* when the difference between them is considerable. The case is somewhat similar to that of comparing different temperatures by means of a very sensitive thermometer, which, notwithstanding very sensible variations of bore, had been calibrated on the assumption that for very considerable portions of the interval which separates the standard points, the bore may be taken as uniform."

This error has been obviated in a chronograph invented by Captain le Boulengé, also of the Belgian Artillery, in which the time is measured by the space passed over by a falling weight; while the employment of the electro-magnets is the same as in the Navez-Leurs. A long cylindrical rod is suspended vertically by an electro-magnet in connection with the first screen. Another electro-magnet in connection with the second screen suspends a shorter rod, which in falling strikes a trigger which releases a knife so as to mark the zinc tubes attached to the longer rod. These several operations require some definite time, which is allowed for by using a "disjunctor" under exactly the same conditions.

When the shot strikes the first screen the longer rod commences to fall; and when it strikes the second screen the shorter rod commences to fall, and releases a knife to cut the zinc on the longer rod.

The space through which the longer rod has fallen represents (when corrected for the disjunctor reading) the time the projectile has taken to traverse the distance between two screens; and this distance being accurately measured, the velocity of the projectile is easily calculated.

All these instruments before described are only capable of measuring one velocity of a projectile; but it is possible *roughly* to measure the resistance of the air by using two different instruments, so as to get two velocities at two different points in the path of the projectile.

We are indebted to the Rev. F. Bashforth, B.D., Professor of Mathematics to the Advanced Class of Artillery Officers at Woolwich, for the accurate experimental investigation of the law of the resistance of the air to projectiles moving at a high velocity.

His chronograph consists essentially of a cylinder mounted vertically with a horizontal fly-wheel attached to it. Two markers attached to two different electro-magnets mark a uniform spiral on the revolving cylinder. One of the electro-magnets is connected with a galvanic battery which circulates through the screens, usually ten, which are placed at equal intervals apart. The other electro-magnet is connected with a galvanic battery, which is so arranged that a pendulum clock beating seconds interrupts the galvanic current once a second, and so moves the marker out of the uniform spiral, and thus gives a scale of time. When the circuit which circulates through the screens is broken, the marker in connection with the first electro-magnet is moved out of the uniform spiral, thus giving as many marks as there are screens. These intervals are carefully measured, and compared with the time scale; whence the velocity at the middle point of each space between the screens is obtained, and the actual resistance of the air at those velocities.

The *differential* character of this instrument makes the results obtained from it worthy of a high degree of credit, "since in this way each experiment supplies means of testing the accuracy of the results, which are *wholly wanting* when only two intervals of time are measured, and that by two different instruments."* The committee further report "that they do not think that any means existed before of recording a number of successive small intervals of time with the degree of precision and trustworthiness attained by Professor Bashforth's instrument." Professor Bashforth has also introduced a "gravity chro-

* *Vide* Report of the Committee of Reference on Chronographs, published by the War Office.

nograph" for measuring velocities rapidly and accurately on a similar principle. In this instrument only one electro-magnet is used, which is connected with one galvanic current, and the marker, instead of tracing a spiral on the revolving cylinder, makes a small hole on the paper. The time, half a second, is measured by a weight falling freely through a space of 4·02 feet. When the weight commences to fall the current is broken and a mark is made, then the projectile breaks the current when passing through the screens, usually three, thus giving three marks; and finally, when the weight reaches the bottom, the current is again broken, and a fifth mark is registered. Thus—

A (1) (2) (3) .B
. . . .

represents the records on the cylinder. A B, length of half-second; (1) to (2), time on the same scale the projectile takes to pass from first to second screen; (2) to (3), ditto from second to third screen. The second screen is not necessary for the observation of a velocity, but is only introduced as a check to see that the spaces are consistent. Knowing the distance between the first and third screens, the velocity is easily calculated by simple proportion, or can be read off by means of a slide-rule.

By the use of five screens, the resistance of the air can be more accurately determined with the gravity chronograph than by the use of two instruments, either of Boulengé or Navez-Leurs, although not with such thorough reliability as with the chronograph before described, on account of the possible slight variation in the velocity of the fly-wheel, during the half-second.

A chronoscope has also been contrived, by Captain Andrew Noble, of Elswick, for measuring the velocity of projectiles in the bore of a gun. The principle is much the same as in the Bashforth chronograph, but the method of registering the breaks in the current is different. In the Noble chronoscope the mark is given by a spark on a blackened circular disc, made to revolve at a high velocity by means of toothed wheels—the mean velocity of which is measured by a stop-clock. This method of measuring

time is said to give reliable results by those who have used it.

Experiments conducted with the two last-named instruments form the basis of some very valuable knowledge in the science of gunnery, and will proably lead to still further investigations of the subject.

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